Contribution to HiLiftPW-3

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PID 035

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Summary of cases completed: PHASTA, Committee, Spalart-Allmaras

Case	Alpha=8, Fully turb, grid study	Alpha=16, Fully turb, grid study	Other
1a (full gap)	Yes	Yes	B1 Vgrid C/M/F
1b (full gap w adaption)	no	no	
1c (partial seal)	no	no	
1d (partial seal w adaption)	no	no	
Other			

Case	Polar, Fully turb	Polar, specified transition	Polar, w transition prediction	Other
2a (no nacelle)	Yes	no	Yes	C1 Vgrid M
2b (no nacelle w adaption)	no	no	no	
2c (with nacelle)	Yes	no	Yes	C1 Vgrid M
2d (with nacelle w adaption)	no	no	no	
Other				

Case	2D Verification study	Other
3	Yes	
Other		

Summary of cases completed: PHASTA, Simmetrix, Spalart-Allmaras

Case	Alpha=8, Fully turb, grid study	Alpha=16, Fully turb, grid study	Other
1a (full gap)	Yes	Yes	C/M
1b (full gap w adaption)	no	Yes	ongoing
1c (partial seal)	no	no	
1d (partial seal w adaption)	no	no	
Other			

Geometry Model	Grid Type	Grid Level	Nodes	BFaces	Volume Cells
HLCRM-Full Gap	Unstructured Tetrahedra	Coarse	8.0 M	482 K	46.4 M
		Medium	22.4 M	1.27 M	132.4 M

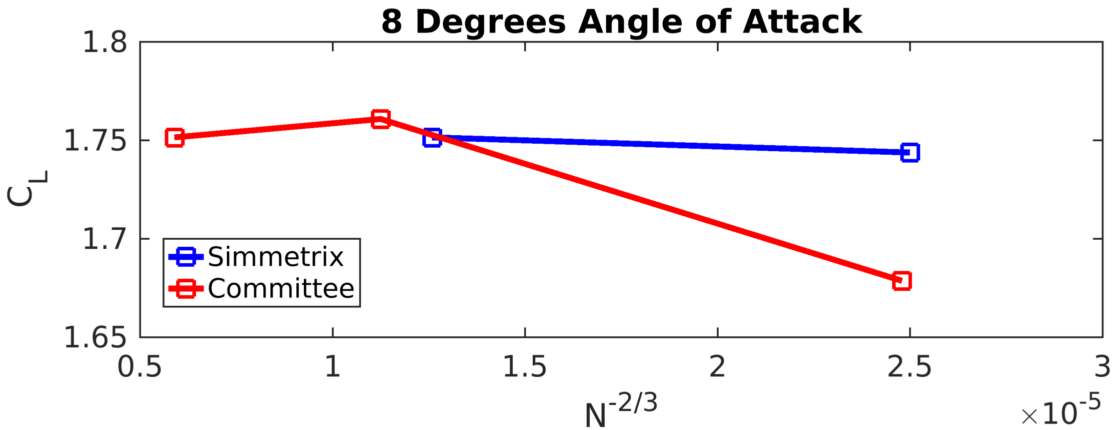
- Simmetrix mesh designed for adaptivity
    - Generated against native CAD (Parasolid kernel)
    - Medium Simmetrix mesh matches Medium B1
    - Coarse Simmetrix mesh doubles surface edge size but keeps wall normal distribution of medium B1.
    - Also some refinement of corners
    - Still comparable size (e.g., B1 sizes are C=8.1, M=26.5, F=69.9 million nodes).

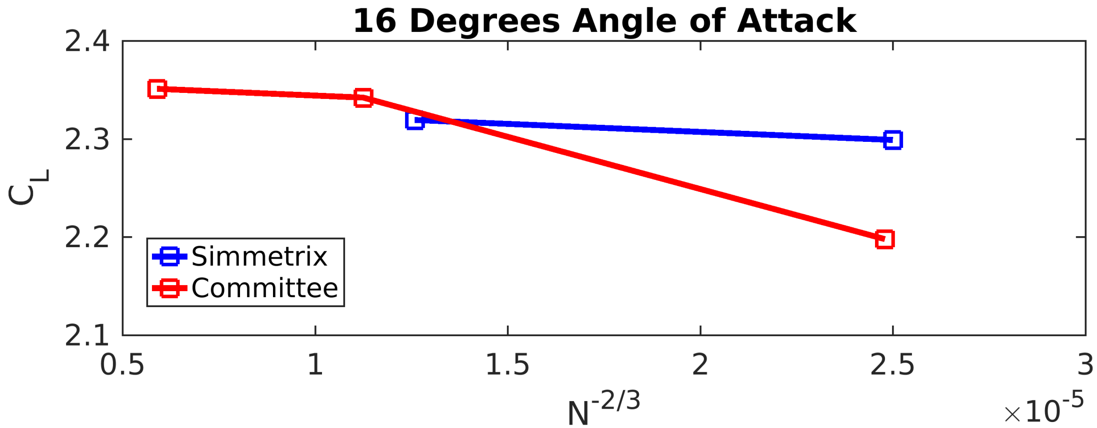
Summary of code and numerics used

- Parallel Hierarchic Stabilized Transient Analysis-PHASTA
  - SUPG finite element method with hierarchic basis, $k<=4$
  - Spatial accuracy demonstrated $O(h^{k+1})$
  - Backward Euler and second order generalized α time integration
  - Compressible and incompressible formulations
  - Scaled to more than 3M processes
  - Adaptivity linked to SCOREC/core and Simmetrix Inc. workflows to allow anisotropic boundary layer adaptivity
  - Results today are k=1, second order accurate in space
- RANS, URANS, and DDES completed on HiLiftPW2, DLR-F11. References:
  - Github.com/PHASTA and Github.com/SCOREC/core
  - AIAA Journal **53**,2,2014 Chitale et al.
  - AIAA 2014-{0749,2570,0117}, 2013-2445
  - AIAA-2017-3243 Vertical Tail Flow Control DDES Validation
  - AIAA-2017-3563 DLRF-F11, HiLiftPW2 RANS, URANS, and DDES

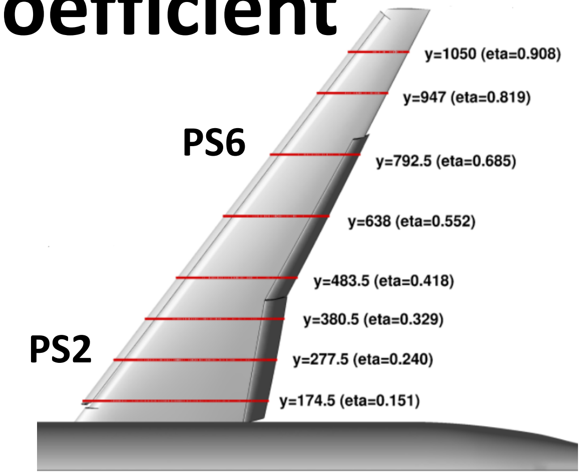
CRM
Grid refinement effects - Forces

- Lift solution convergence, in terms of difference from fine grid result, was somewhat better for coarse grids at both AOA

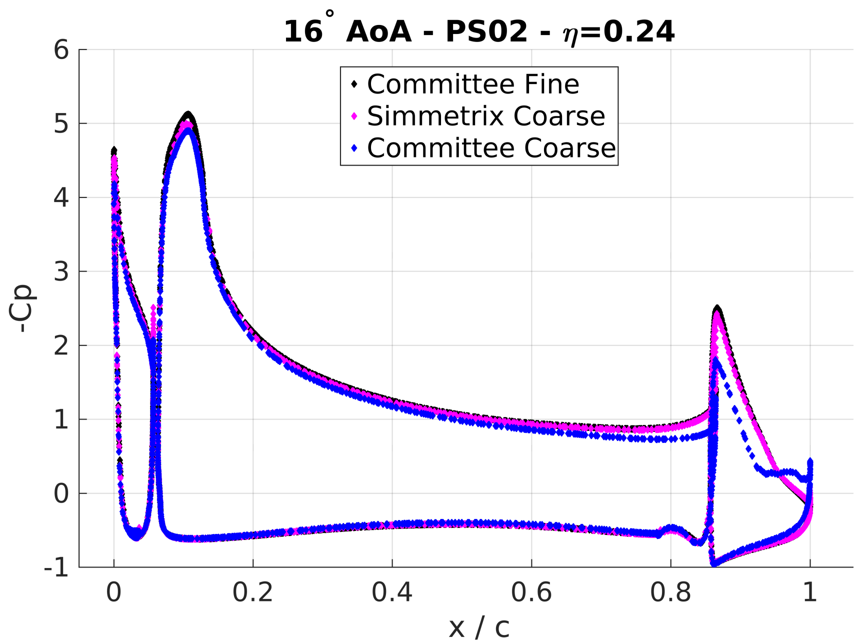


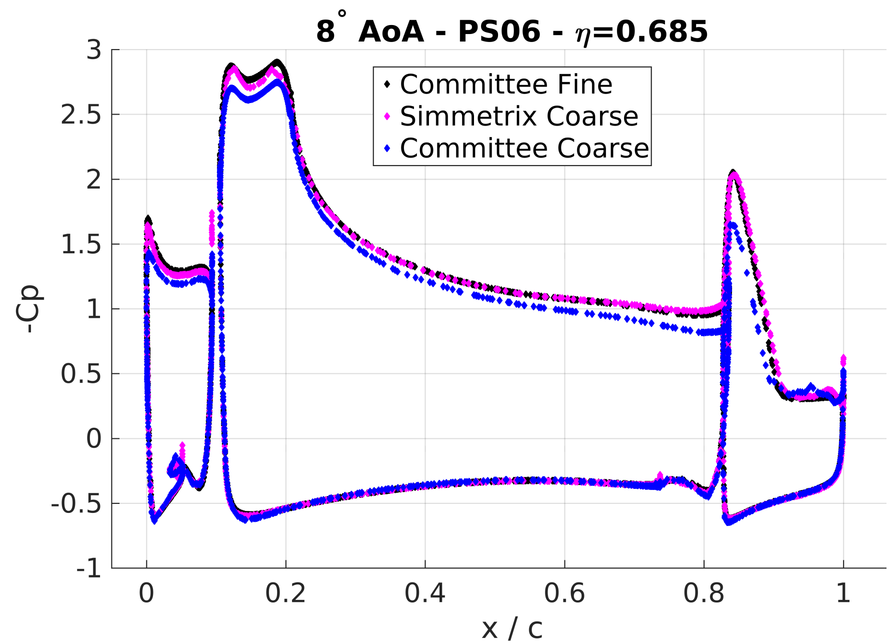


CRM
Grid refinement effects – Pressure coefficient

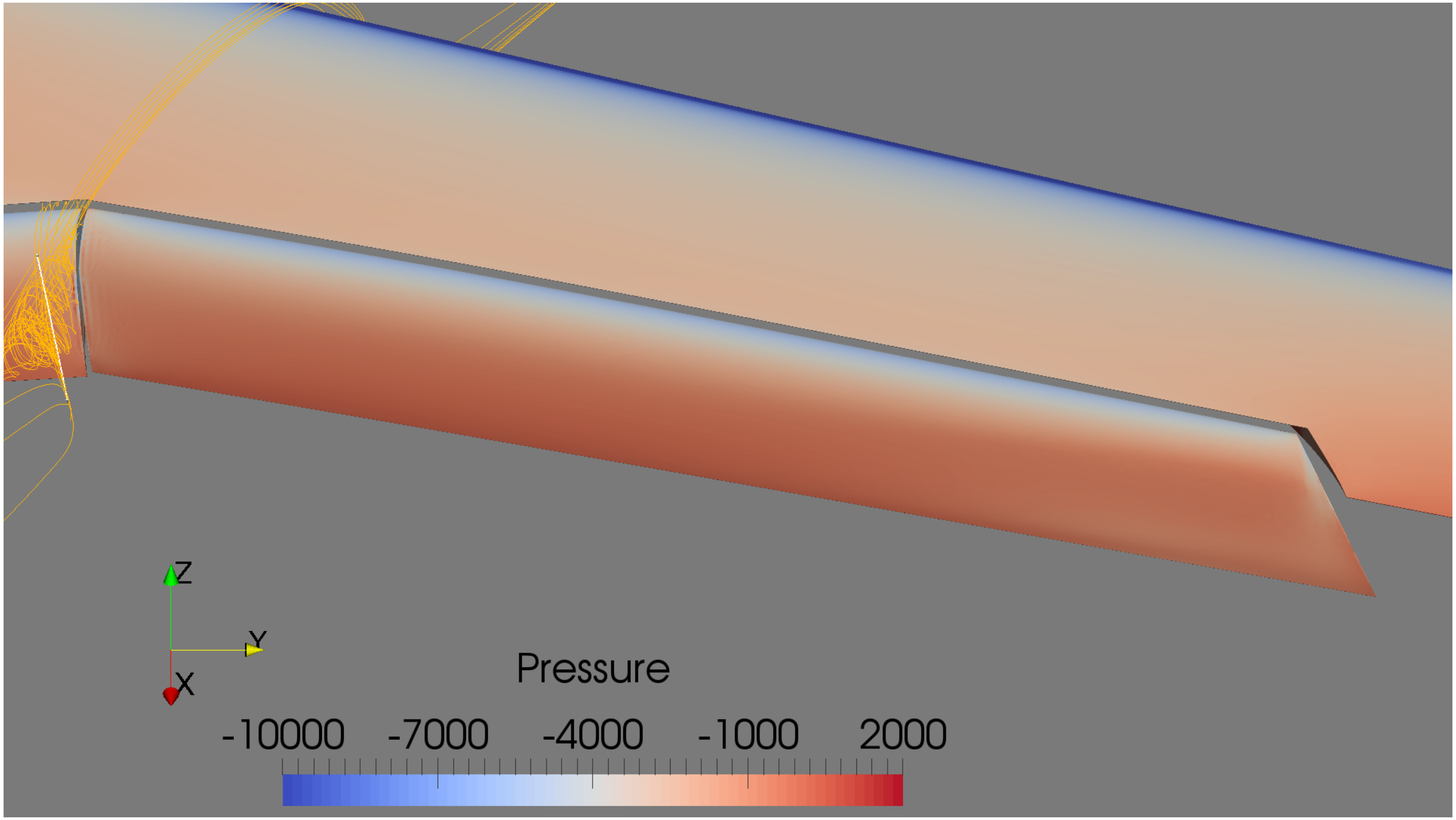


- Better coarse prediction of flap suggests B1 Coarse wall normal distribution likely the largest error source

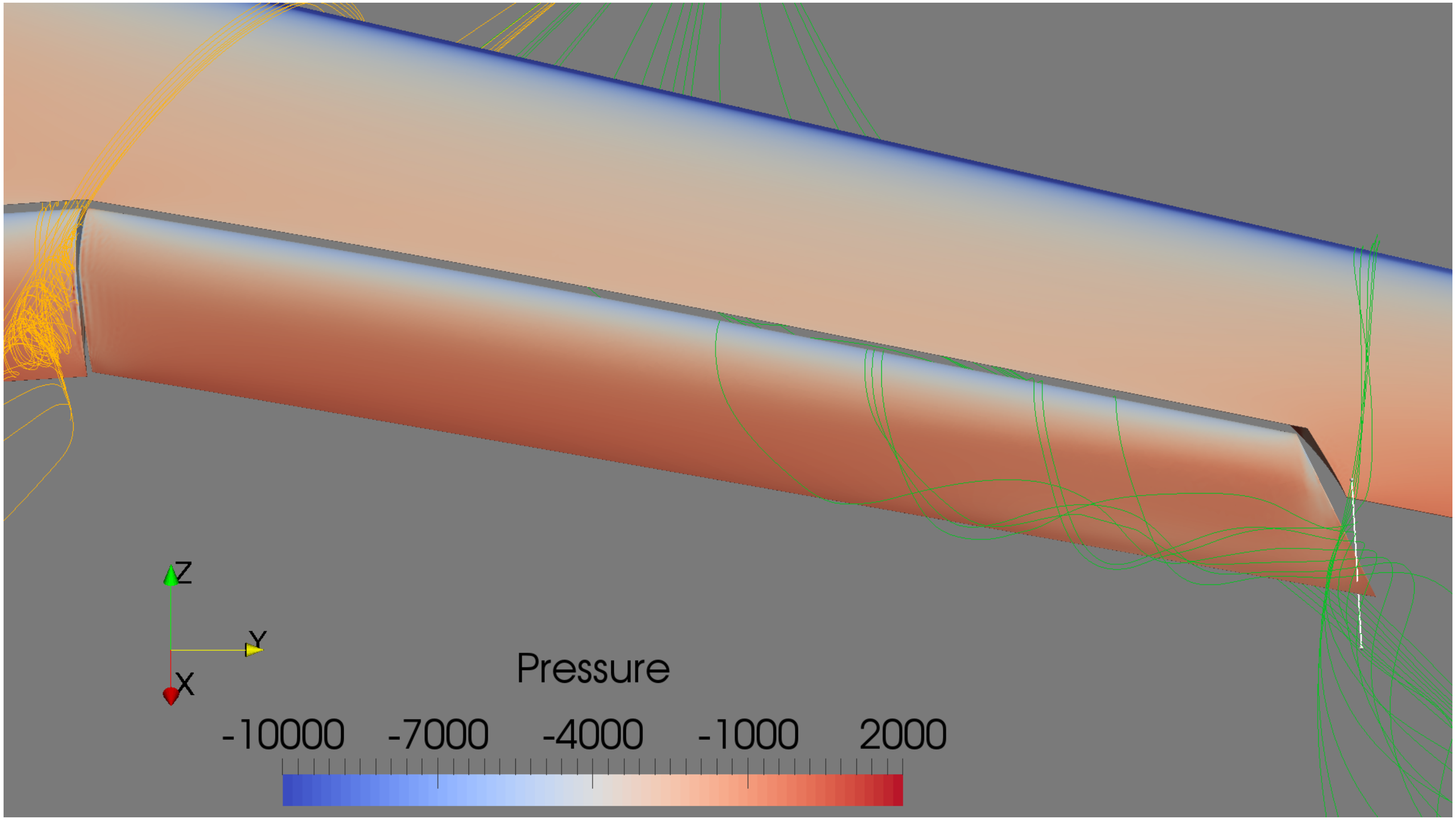




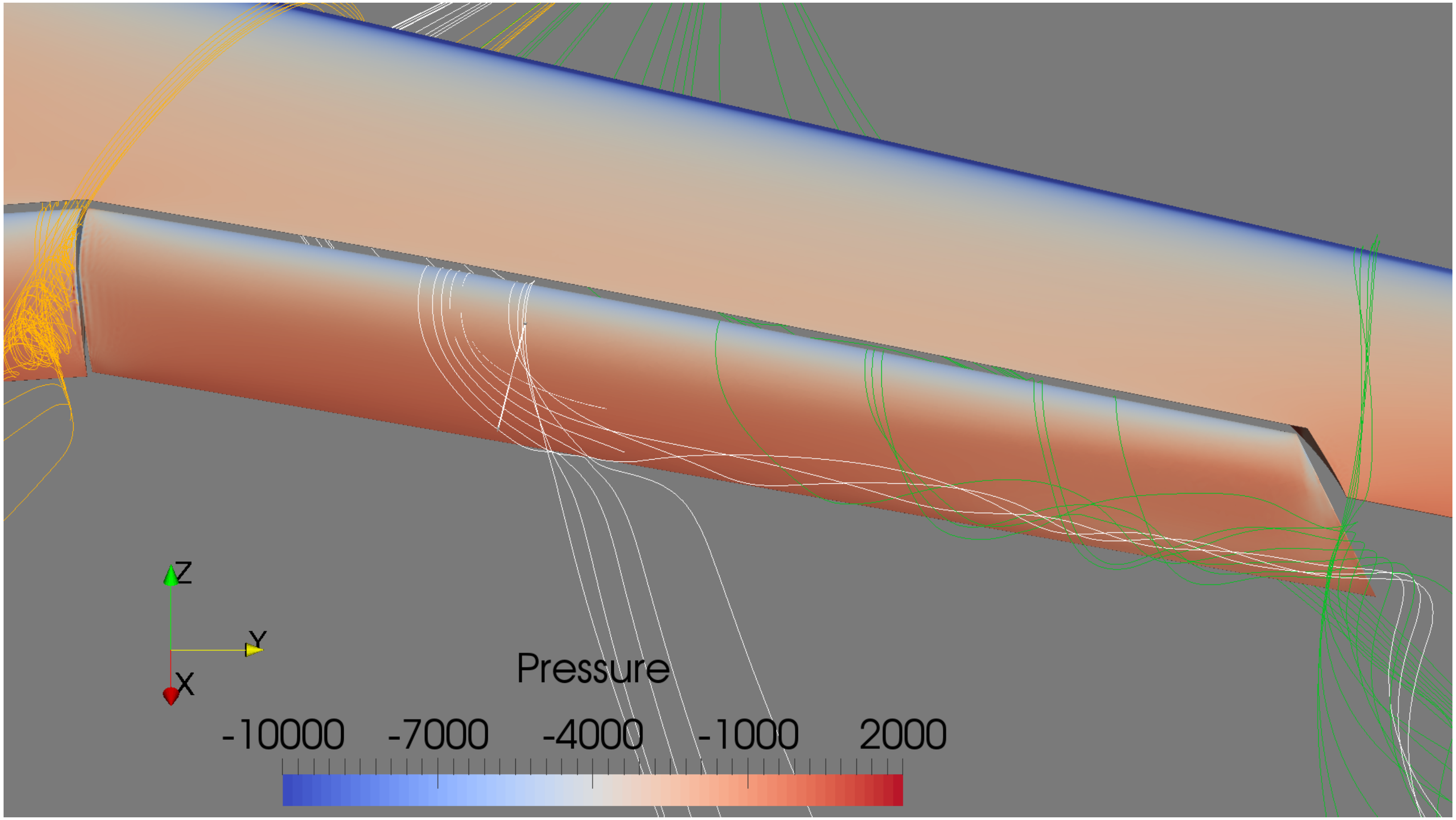
CRM Streamline Placement: Orange:Gap



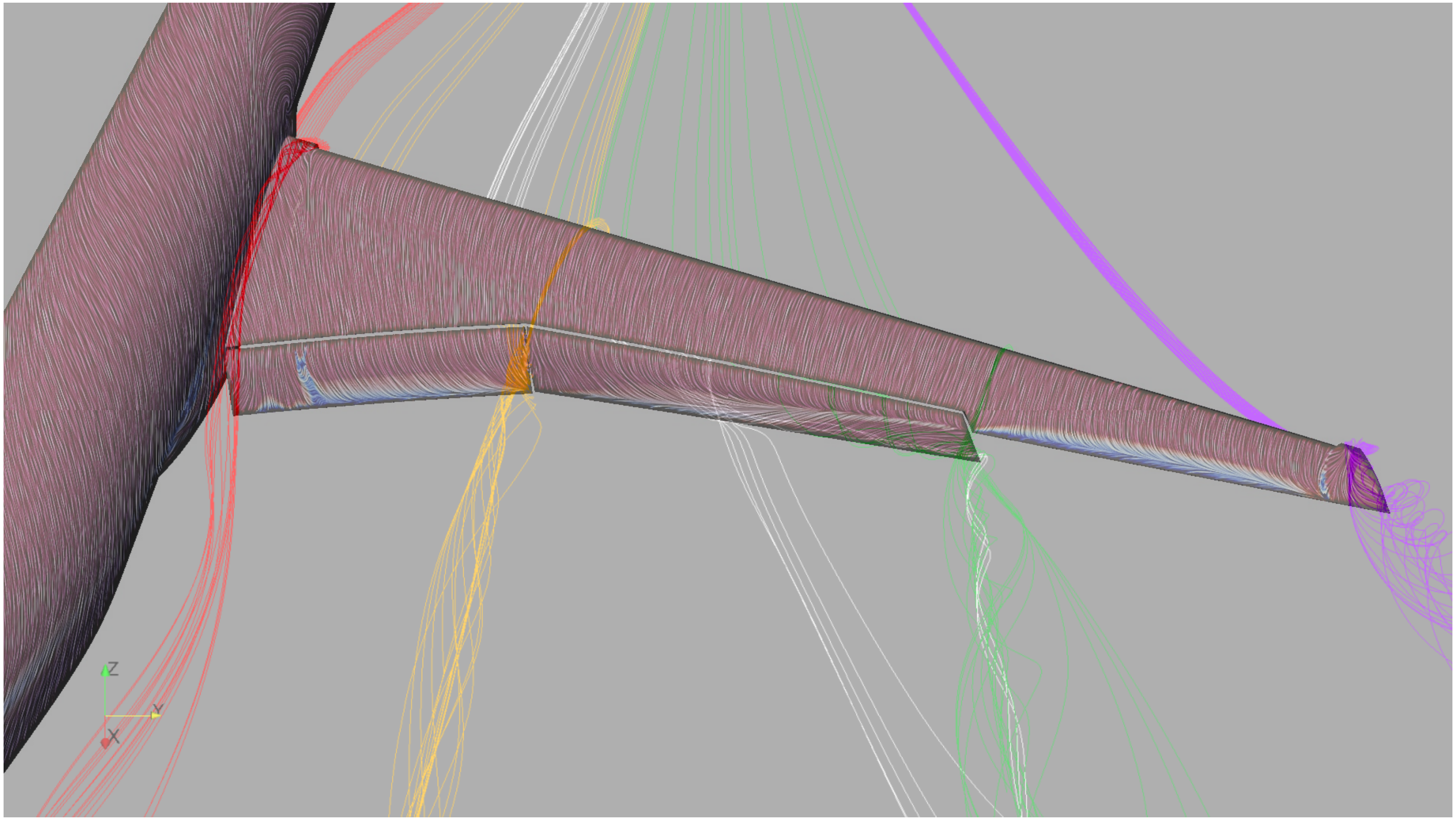
CRM Streamline Placement: Green: Flap Tip



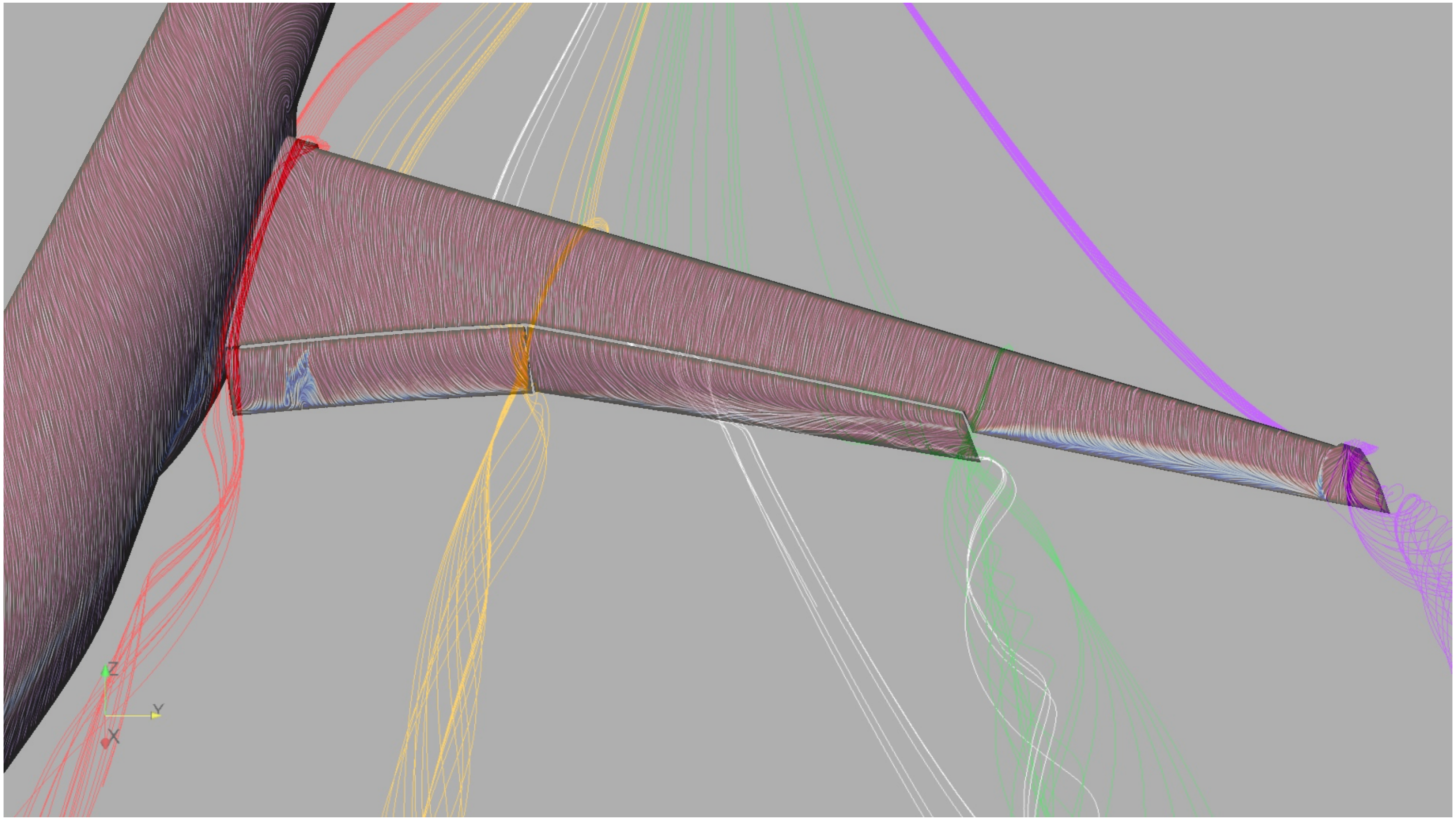
CRM Streamline Placement: White: Near Flap Surface



CRM Wall Shear Stress Streaks and Streamlines: Committee:Fine:16



CRM Wall Shear Stress Streaks and Streamlines: Simmetrix:Medium:16



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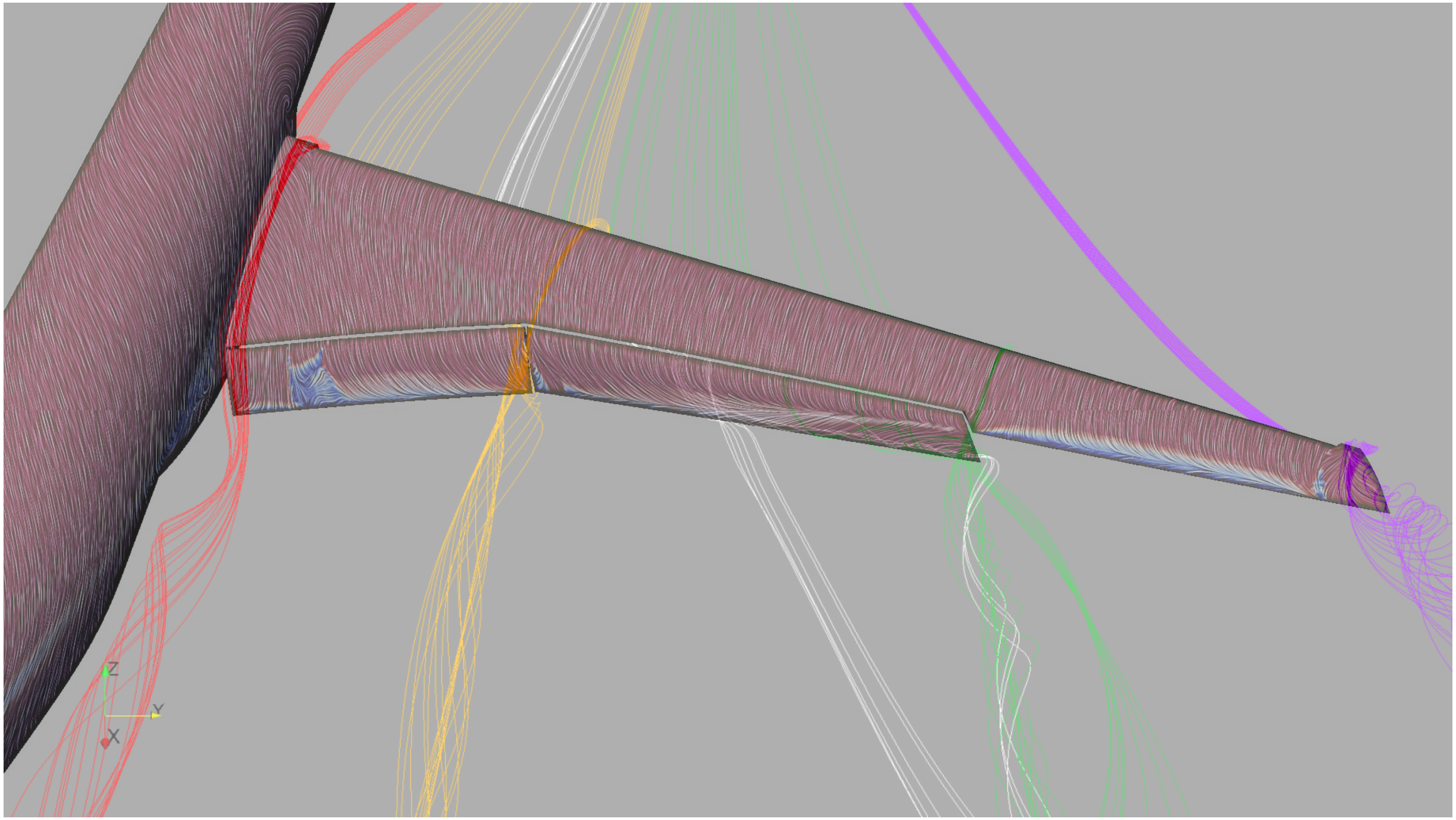
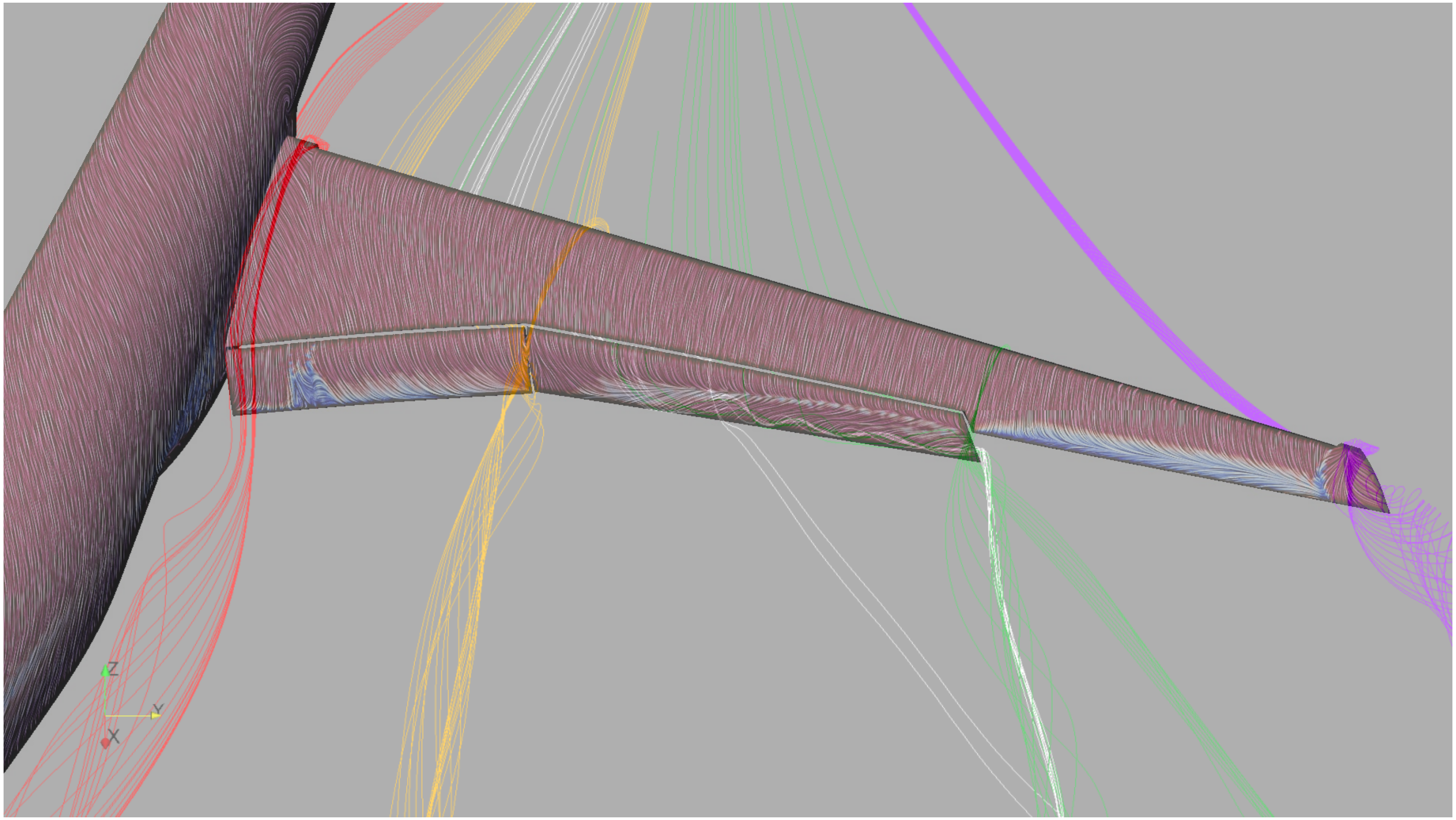


CRM Wall Shear Stress Streaks and Streamlines: Simmetrix:Coarse:16



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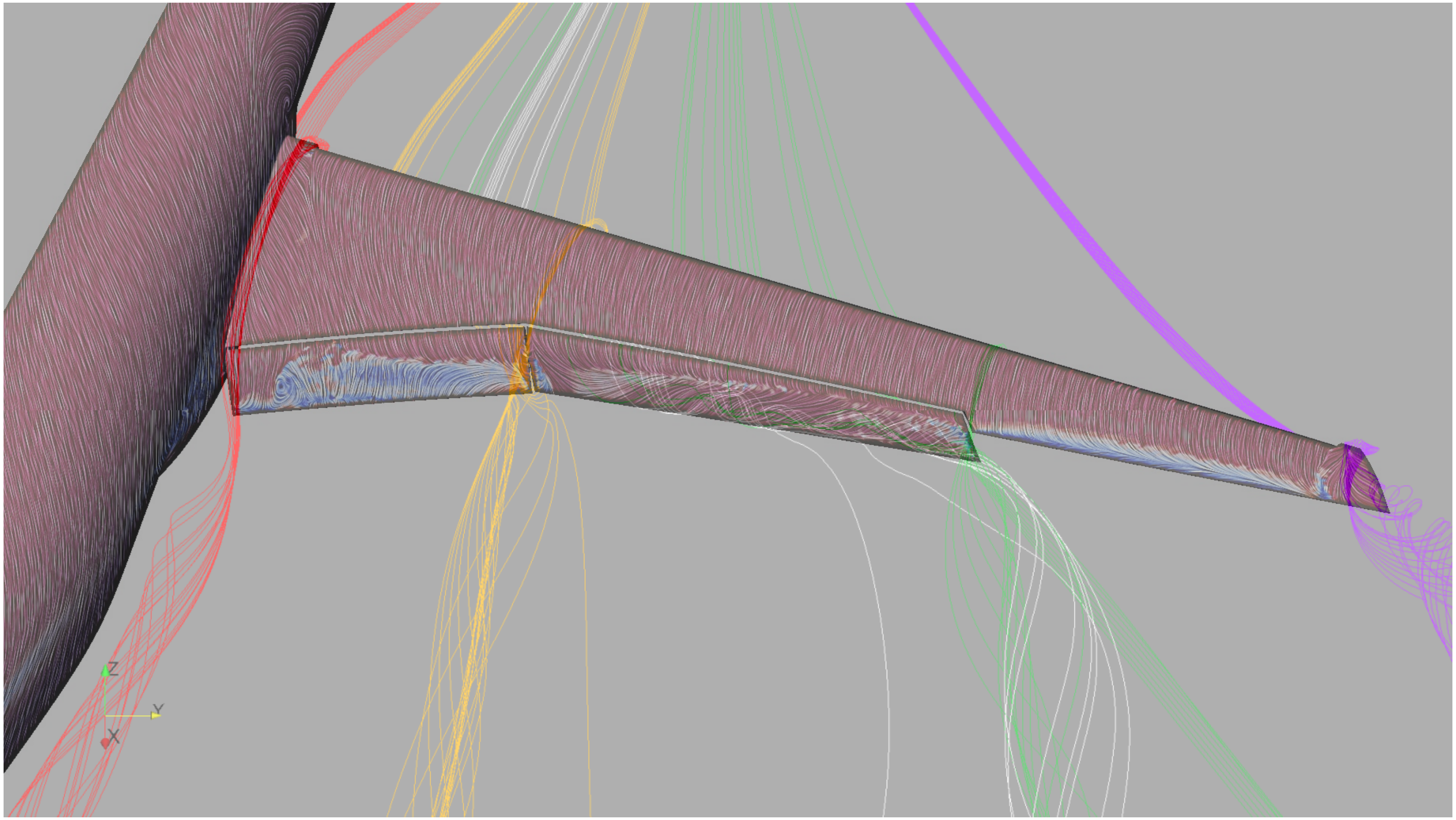

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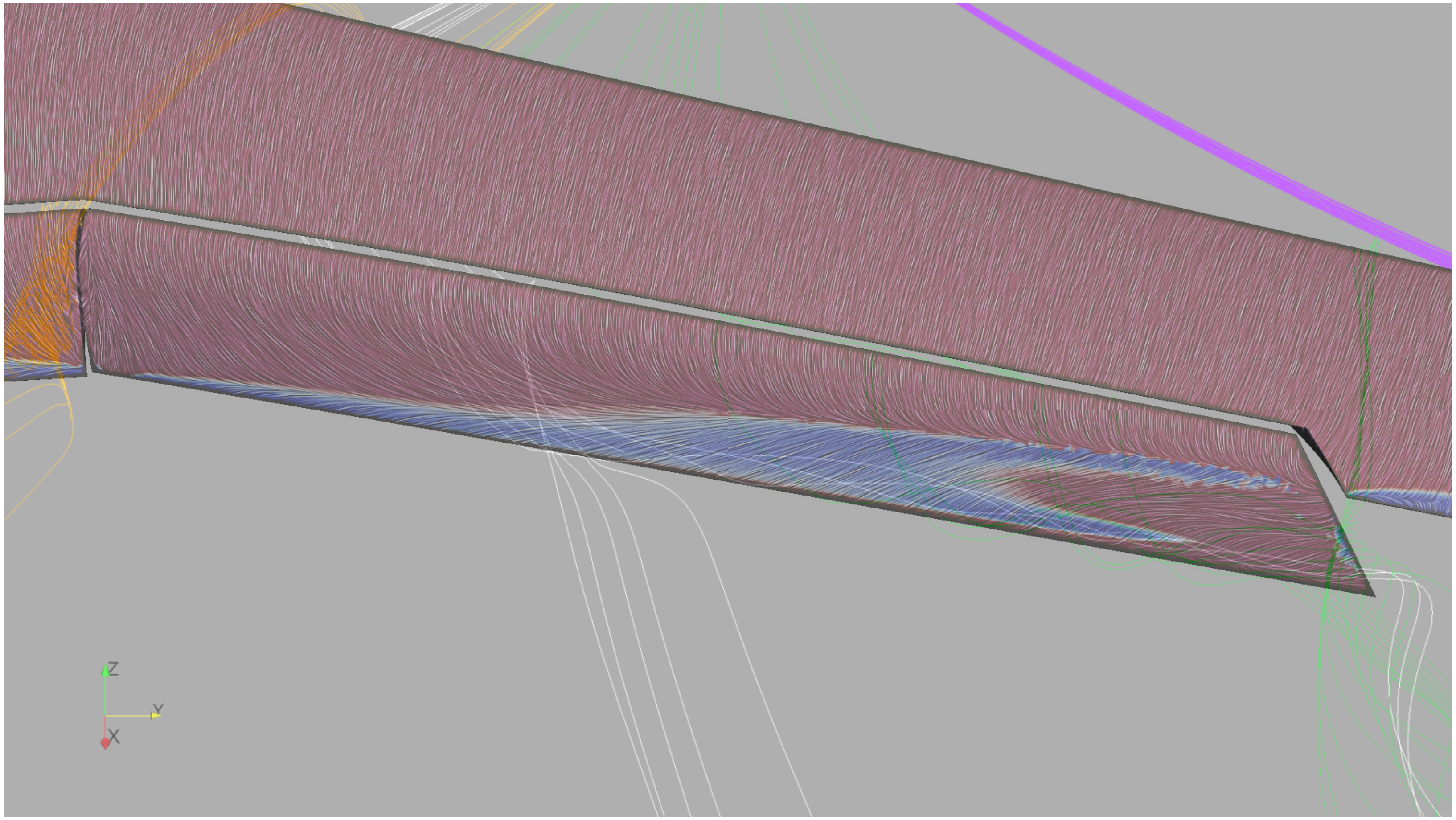
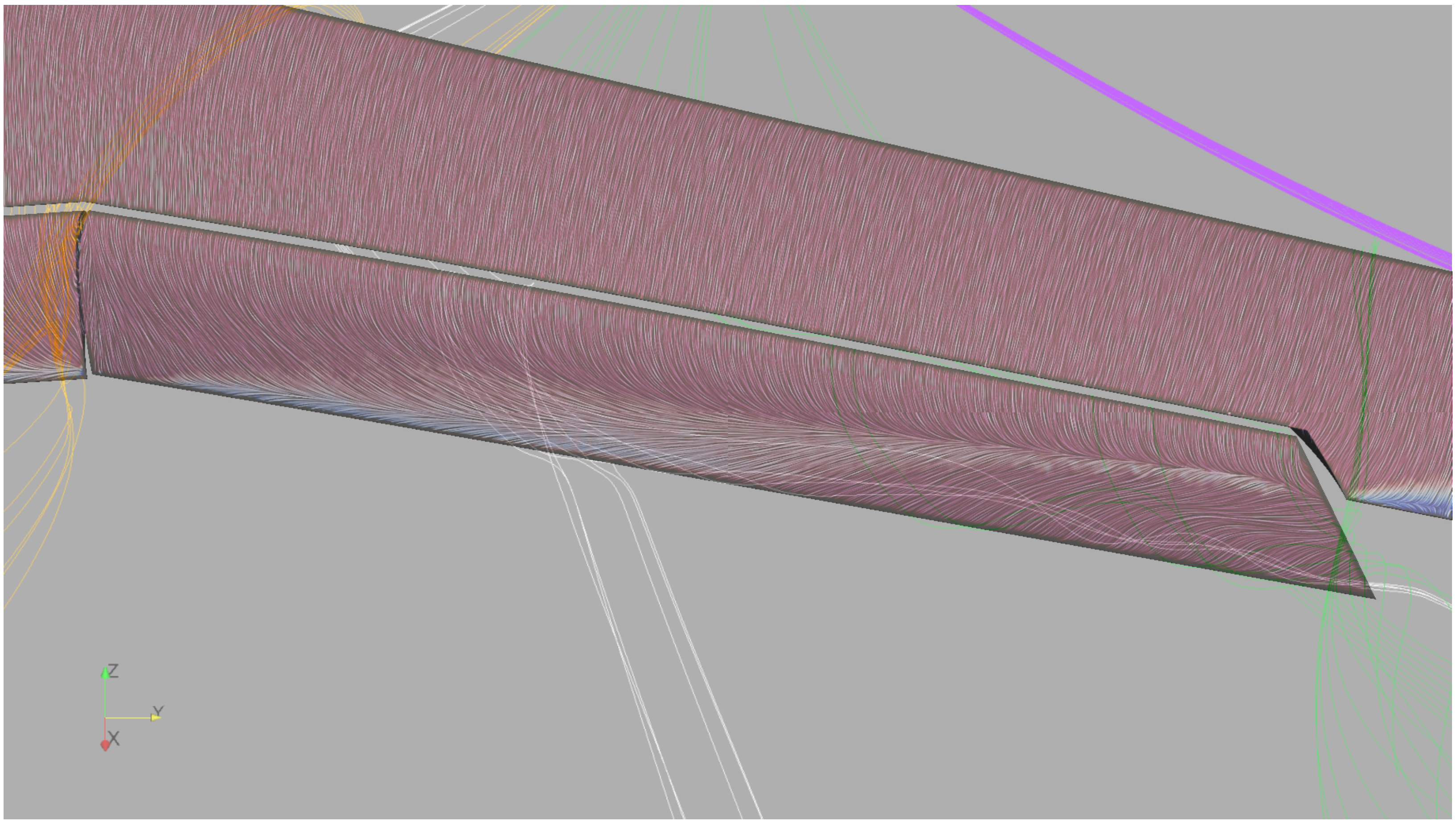


CRM Wall Shear Stress Streaks and Streamlines: Simmetrix:Medium:16



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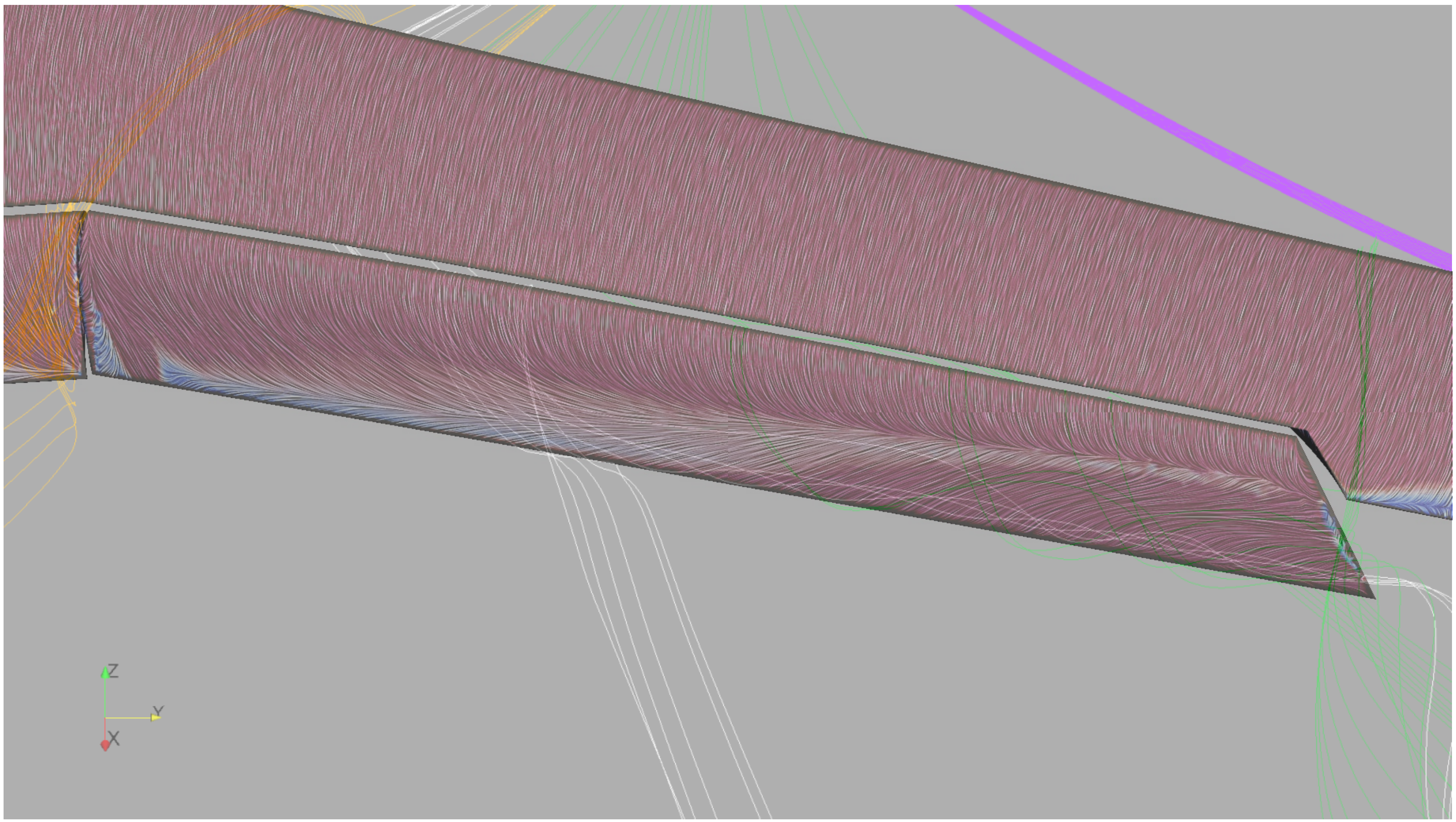

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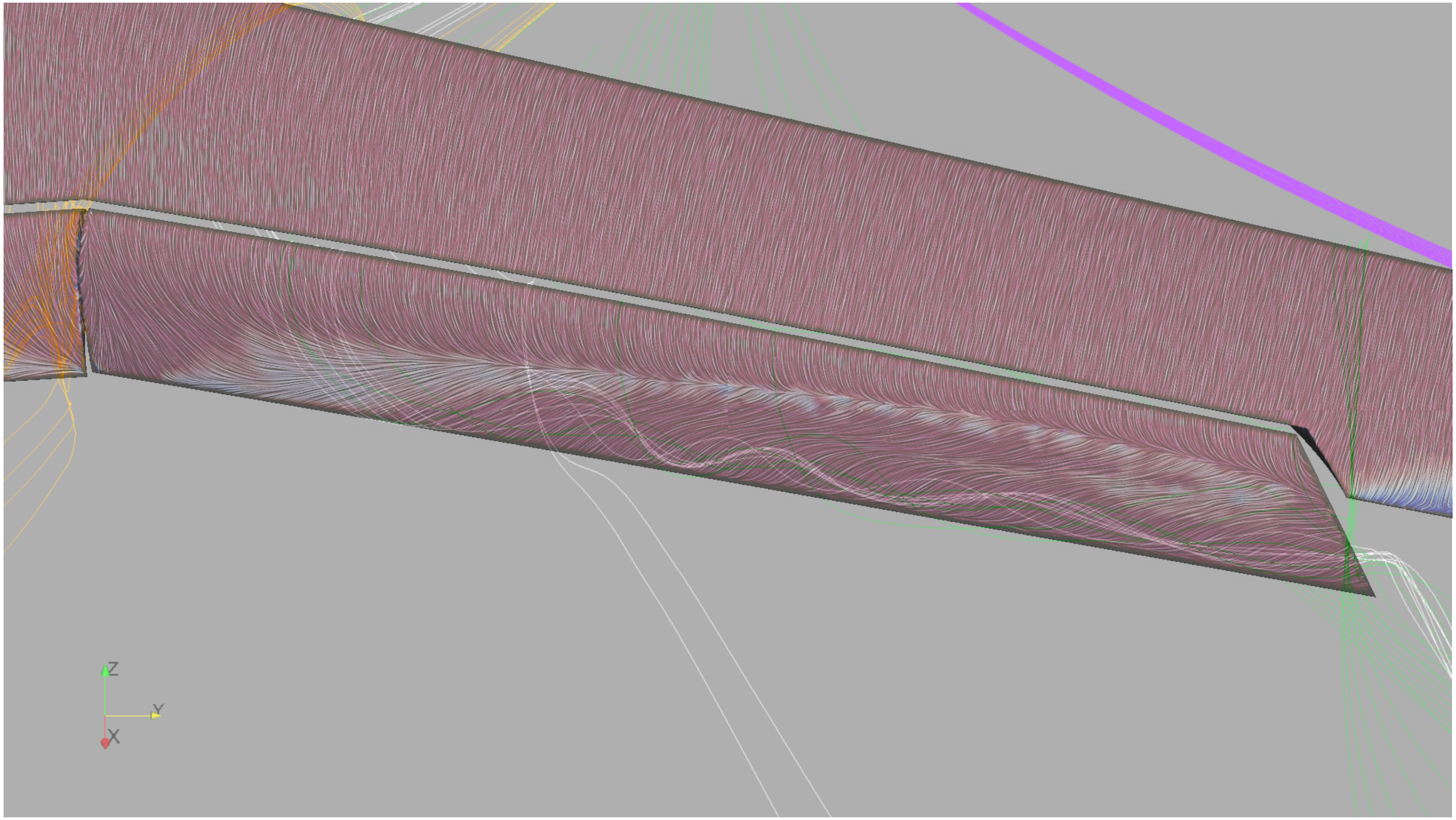

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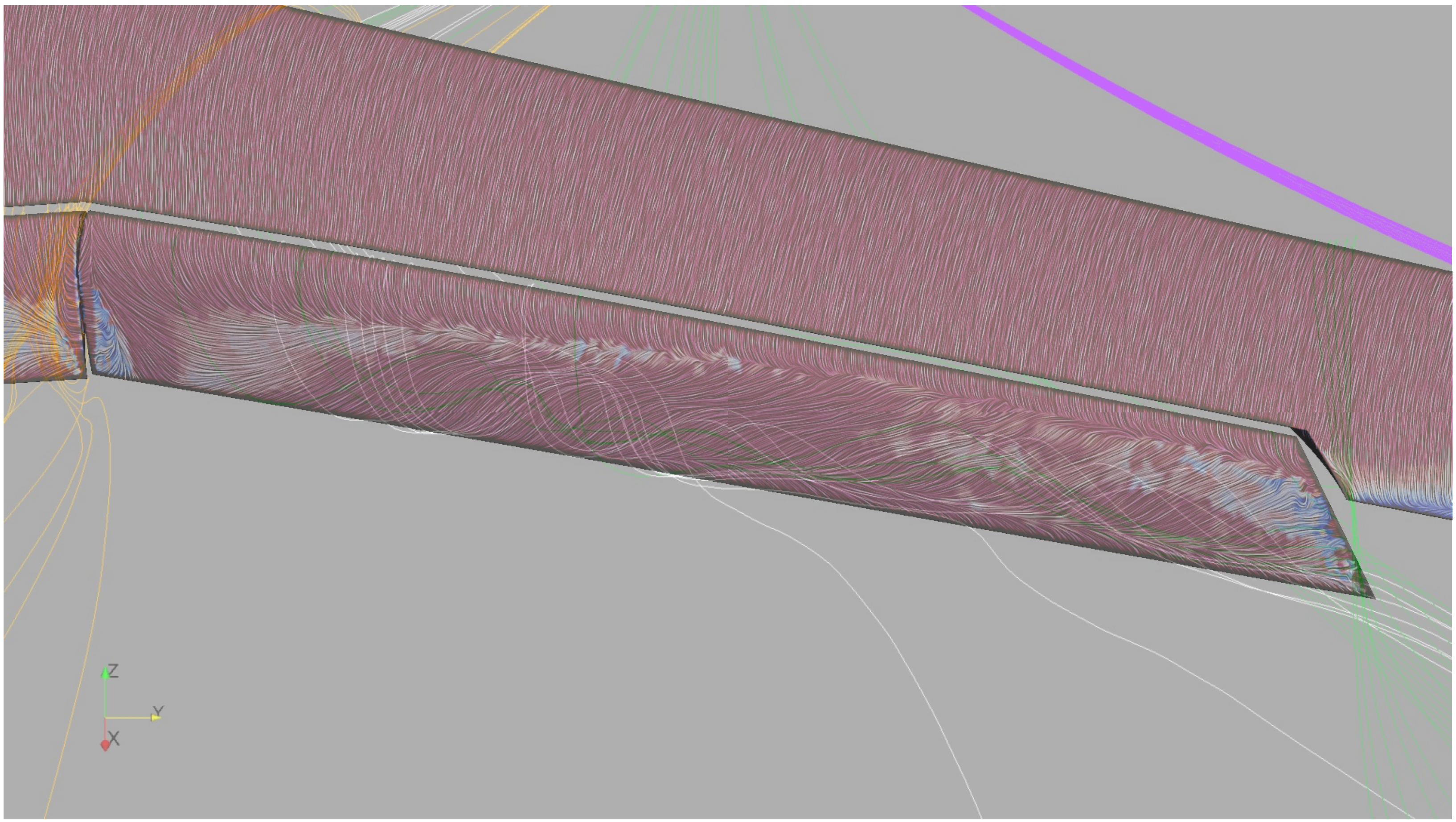
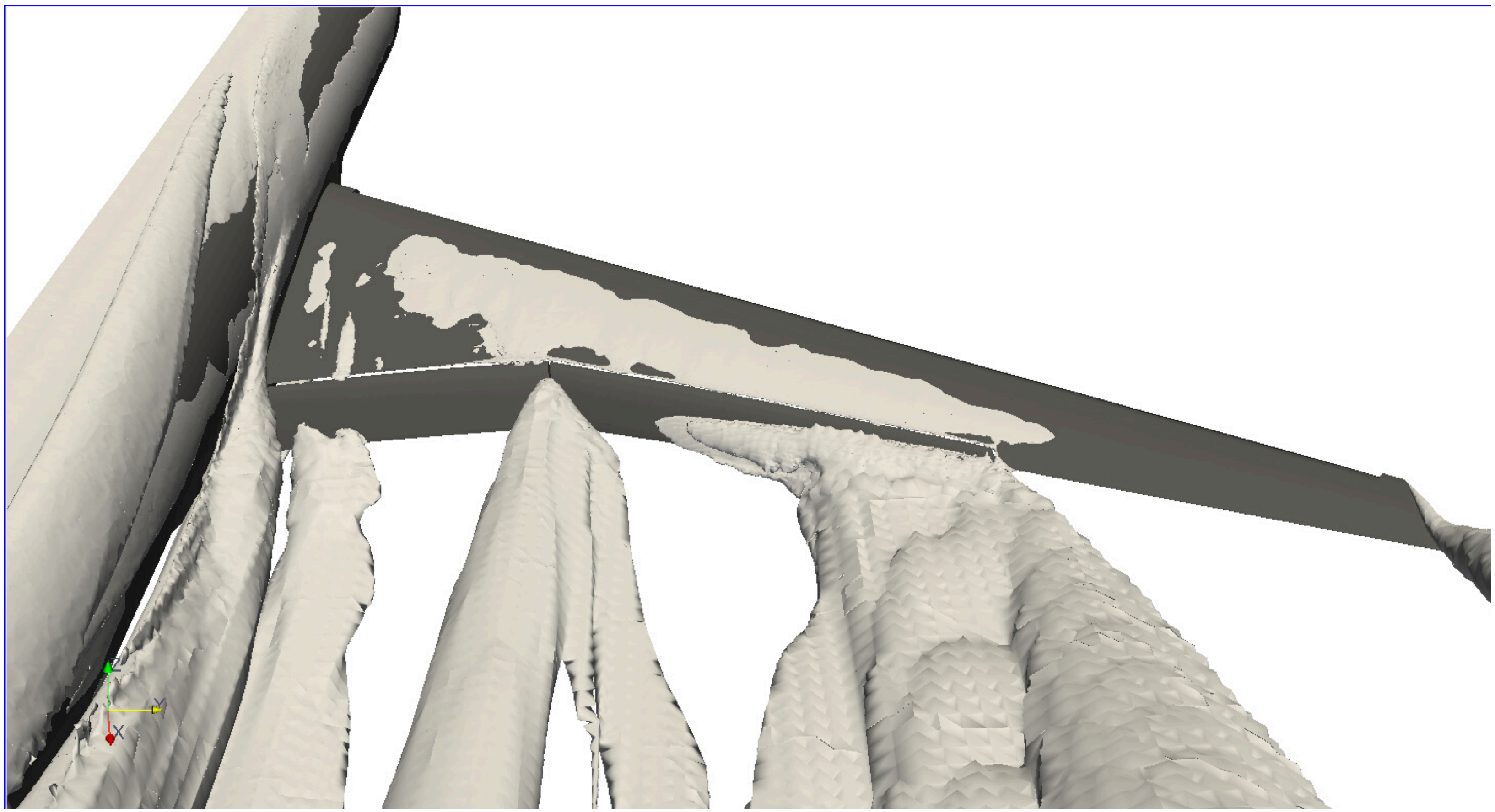
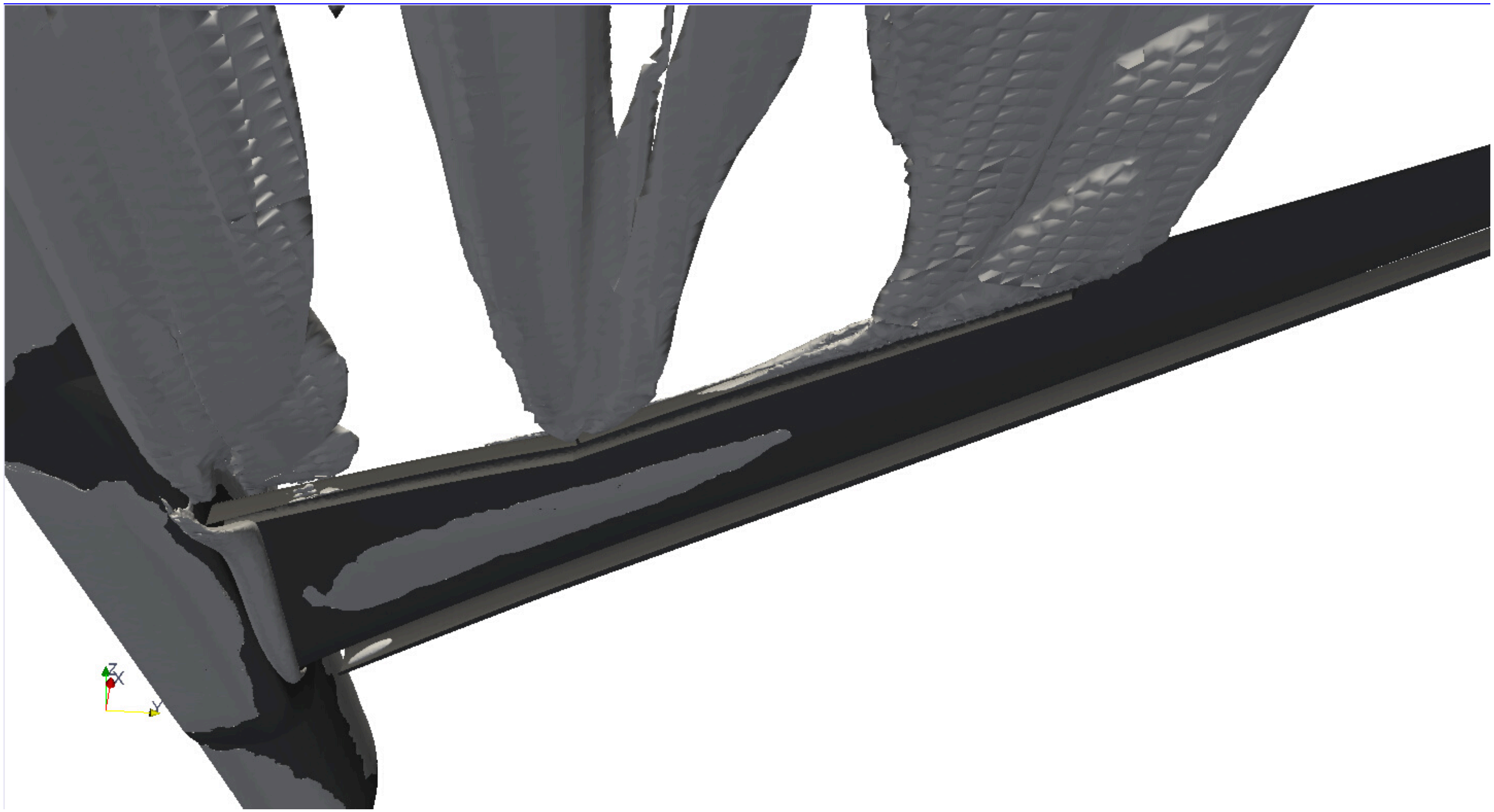


CRM Adaptation Envelope: Simmetrix:Coarse:16

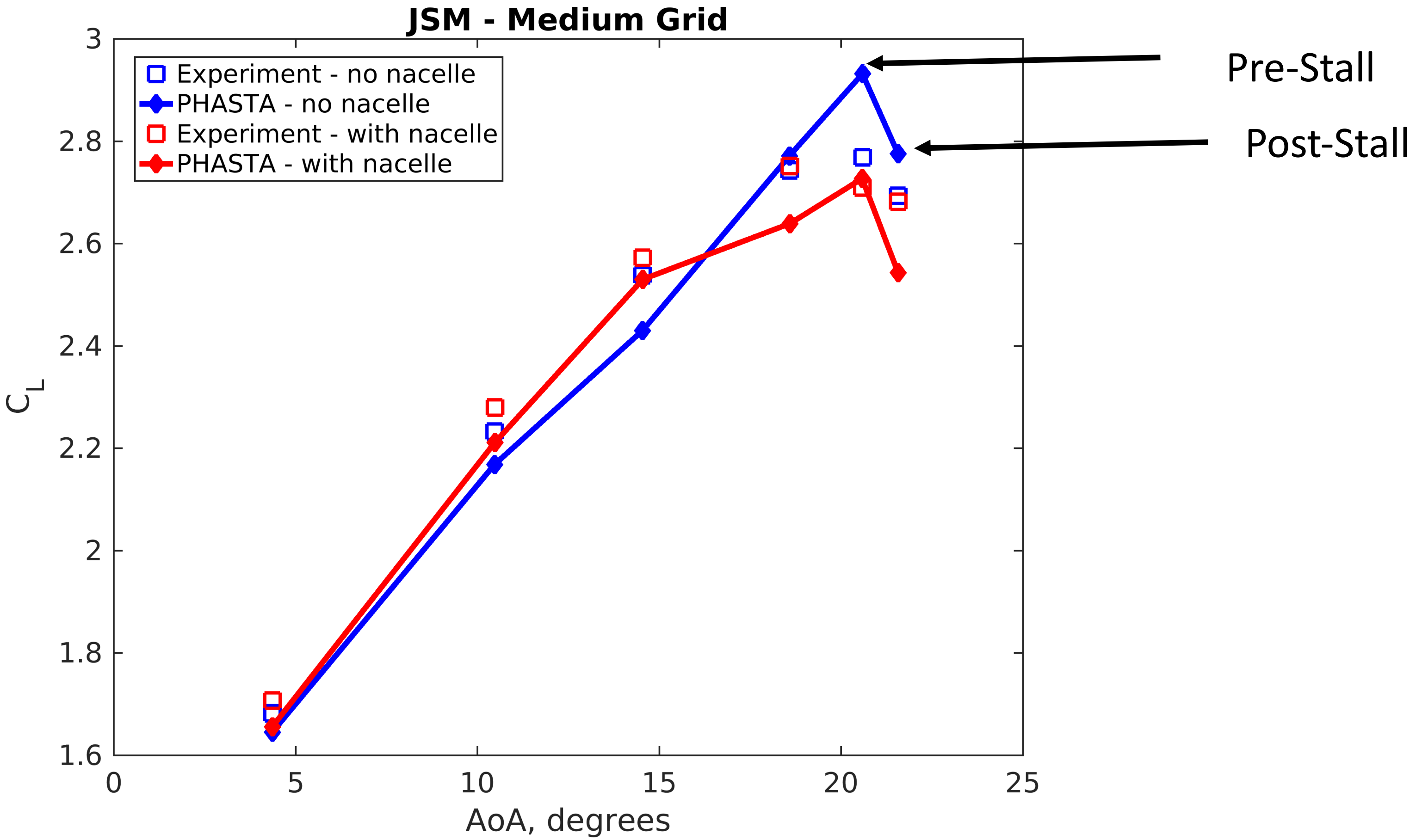


CRM Adaptation Envelope: Simmetrix:Coarse:16

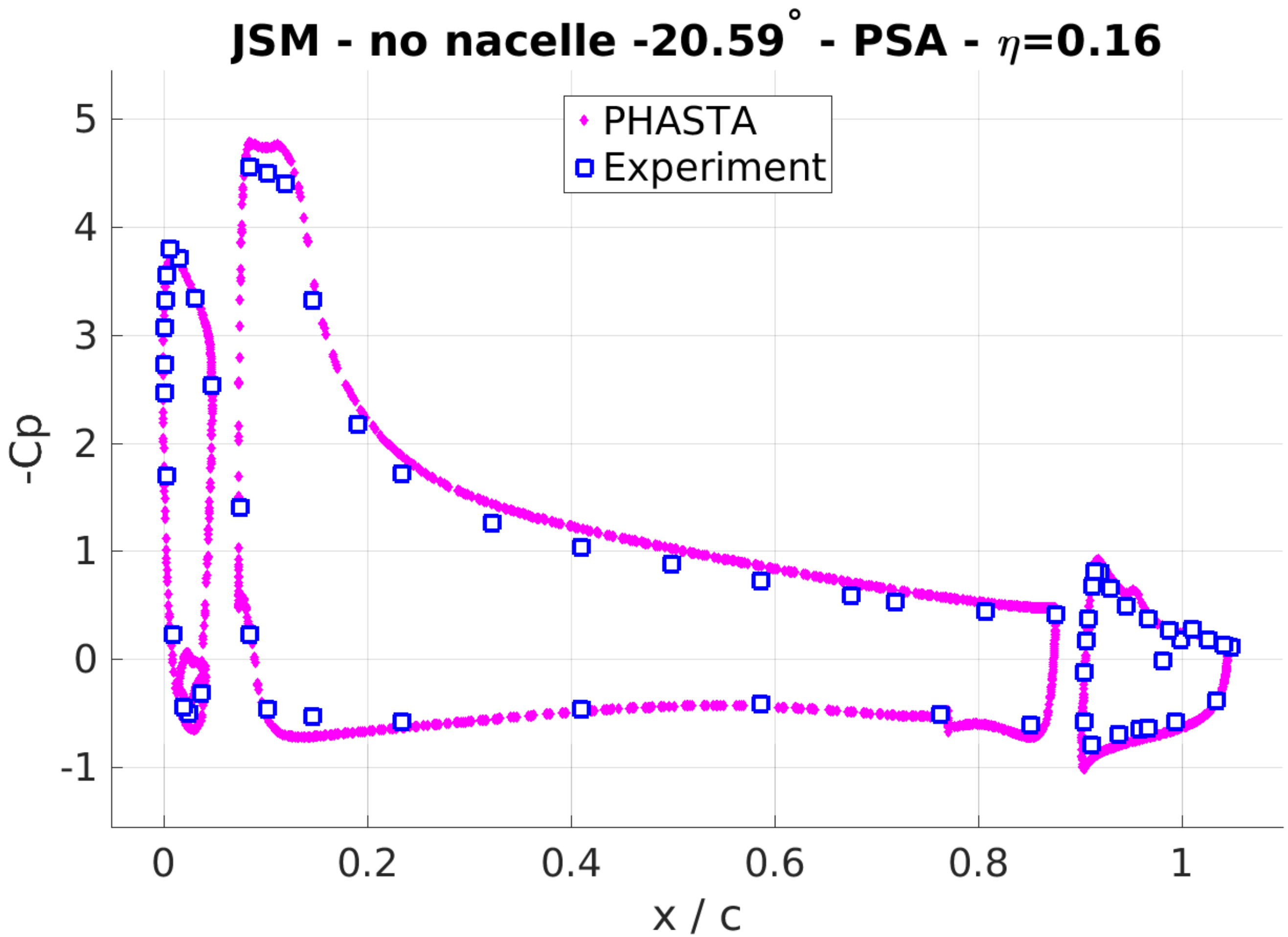


JSM
Aerodynamic forces

- Lift force
  - Stall angle predicted well but lift value off -- surprising given how well the Cp matches.
  - BUT, as with others, stall not the same mechanism as the experiment.
  - Influence of nacelle predicted well at lower AoA, not as much at larger angles.



JSM
Pressure Coefficients: Pre-Stall



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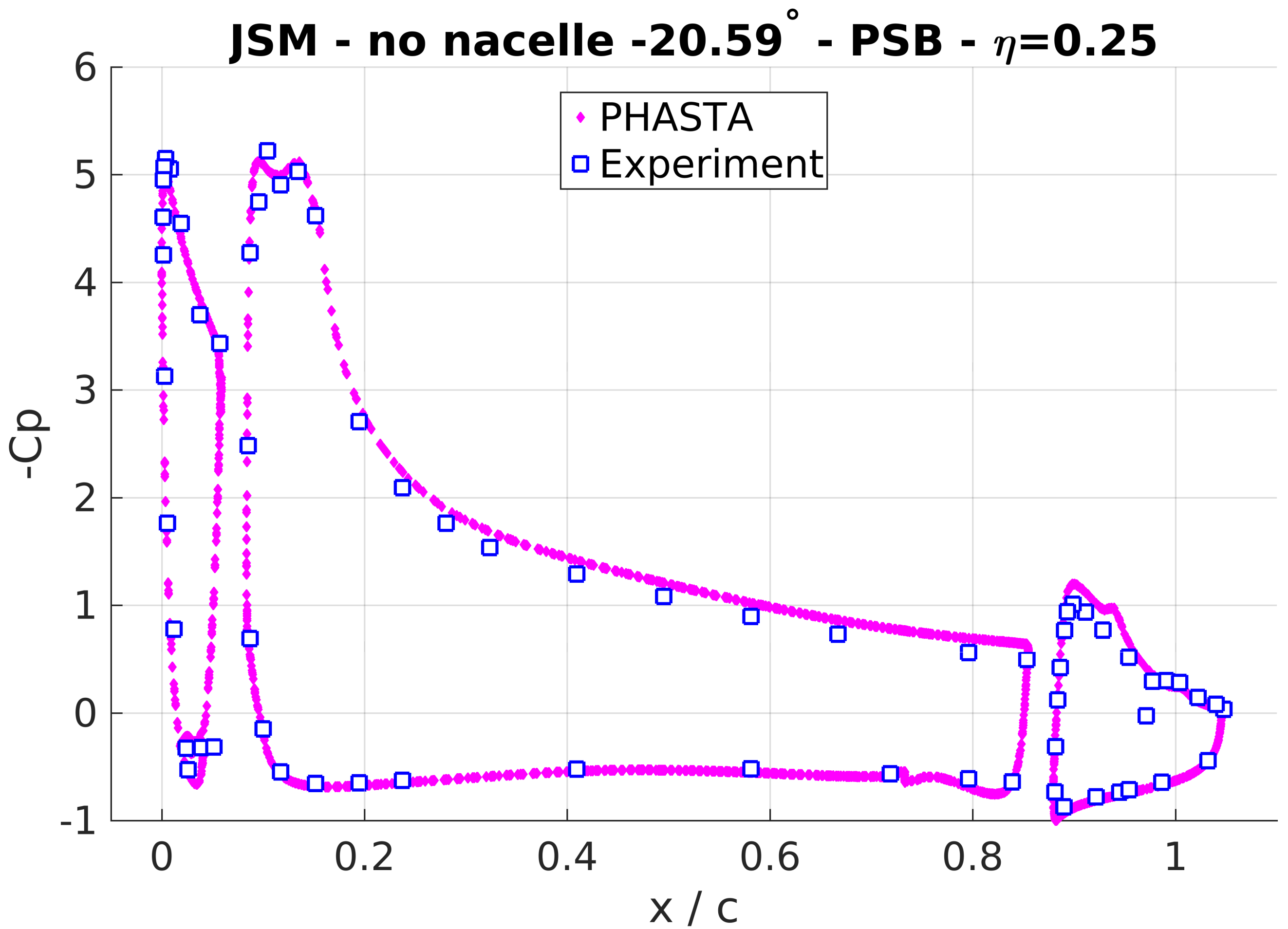

JSM

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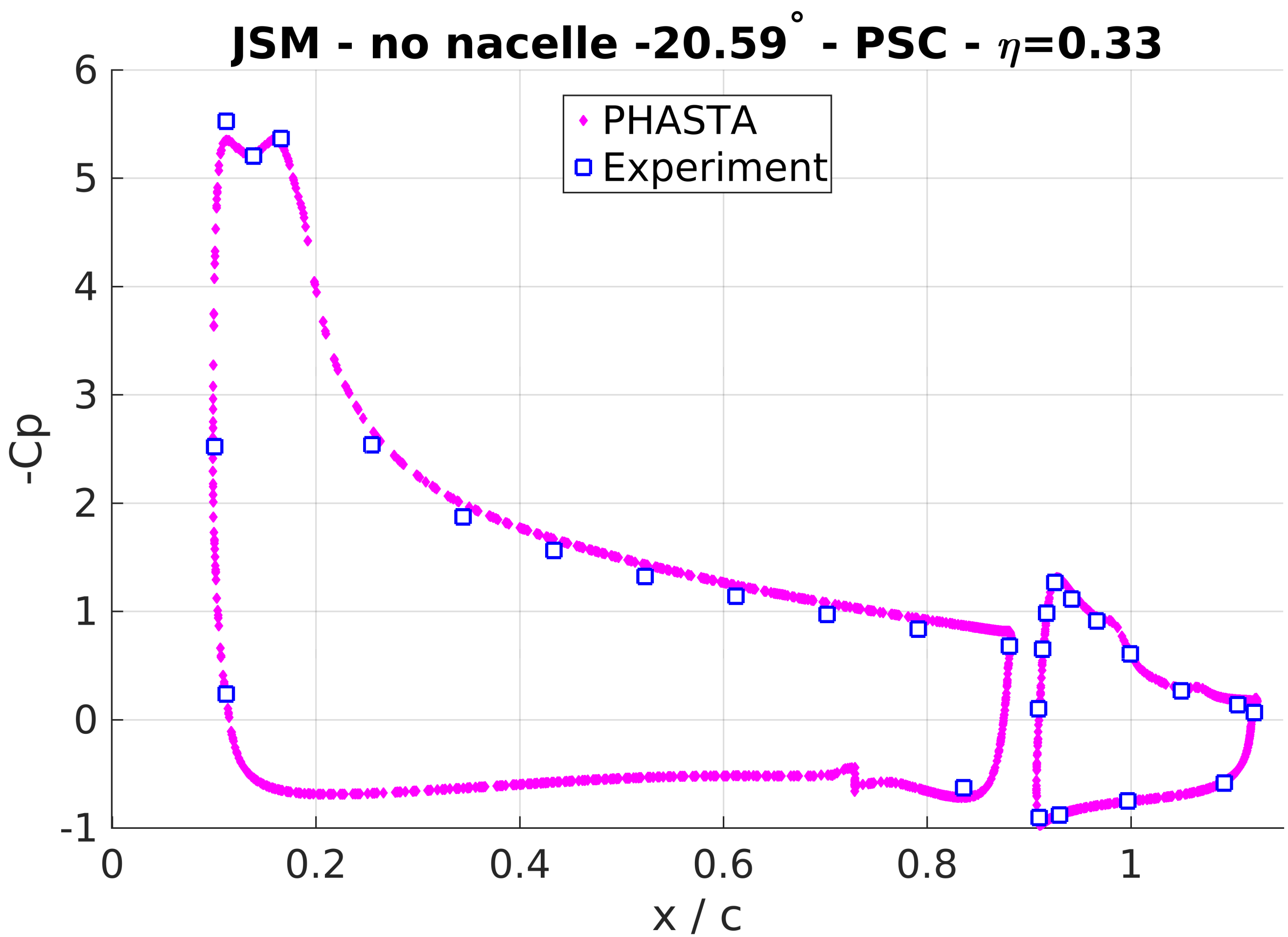

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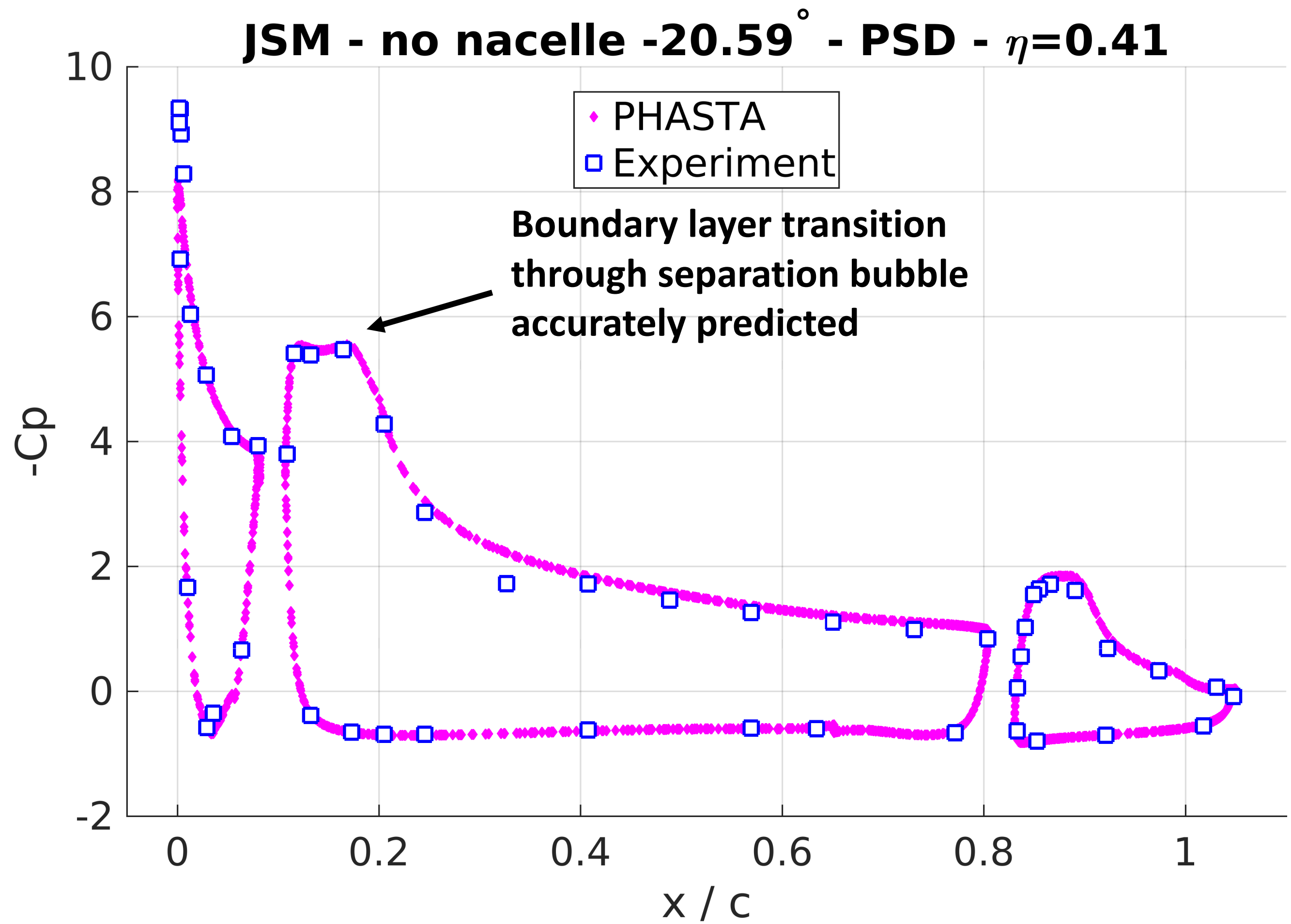

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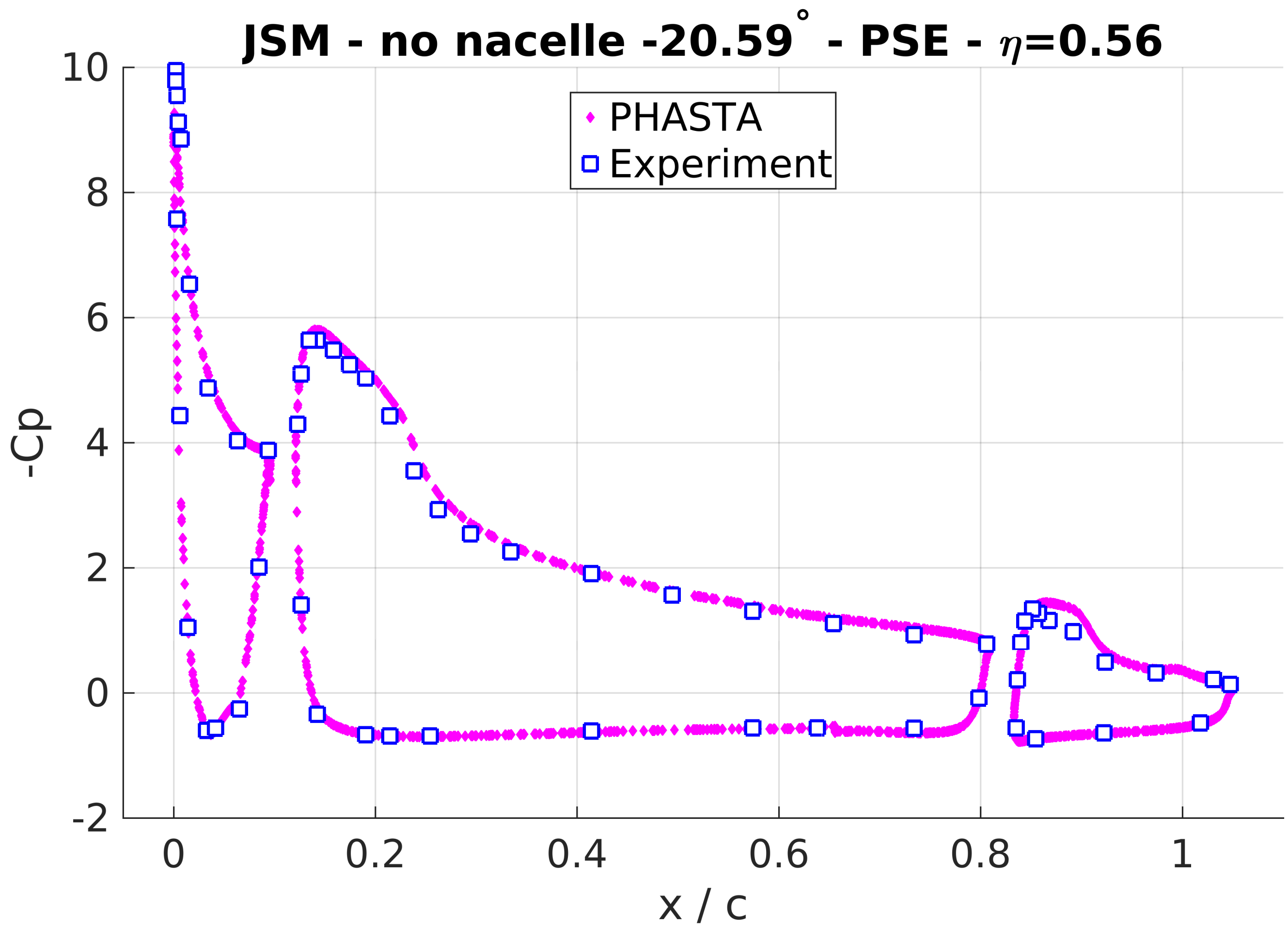

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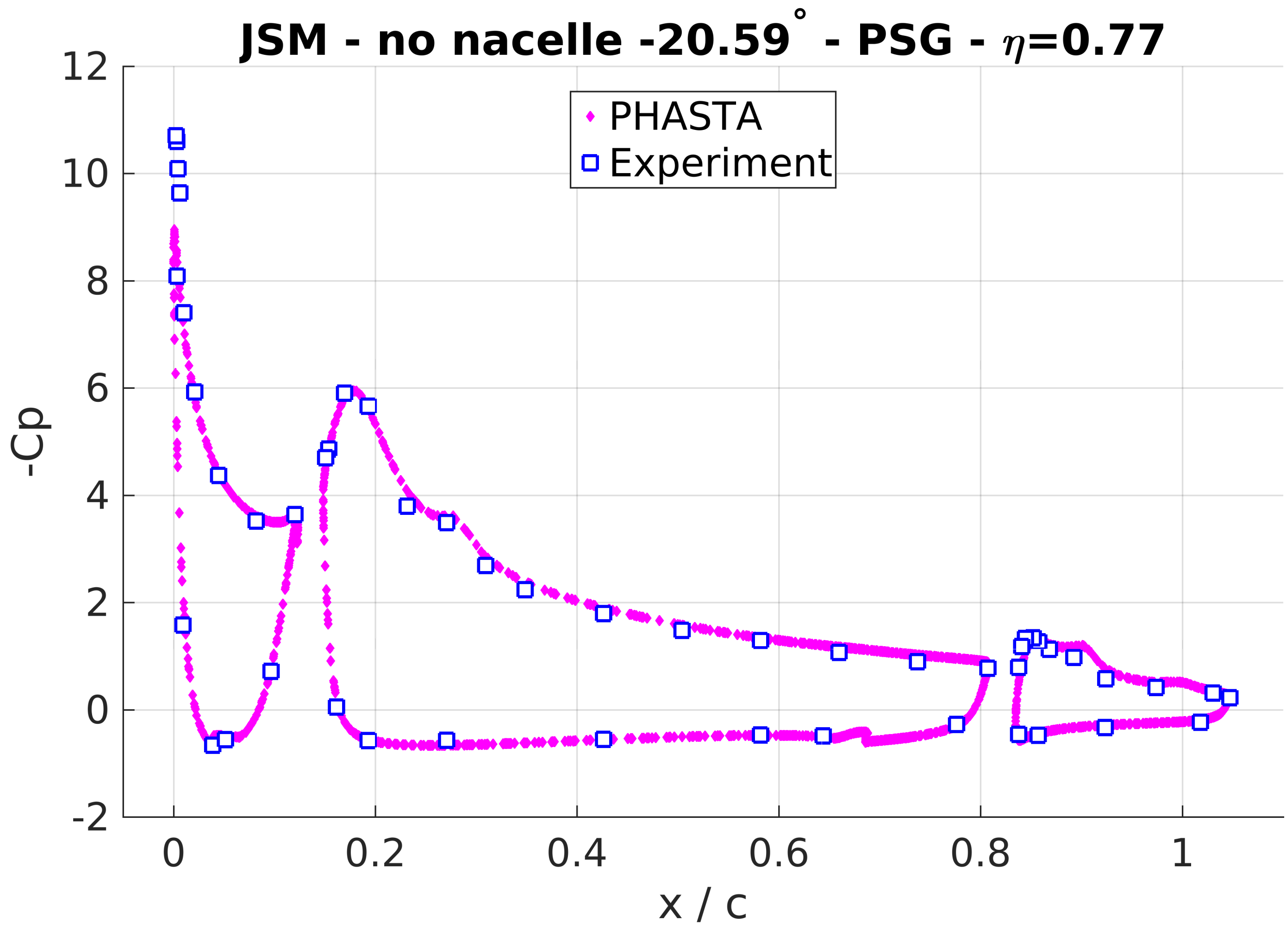
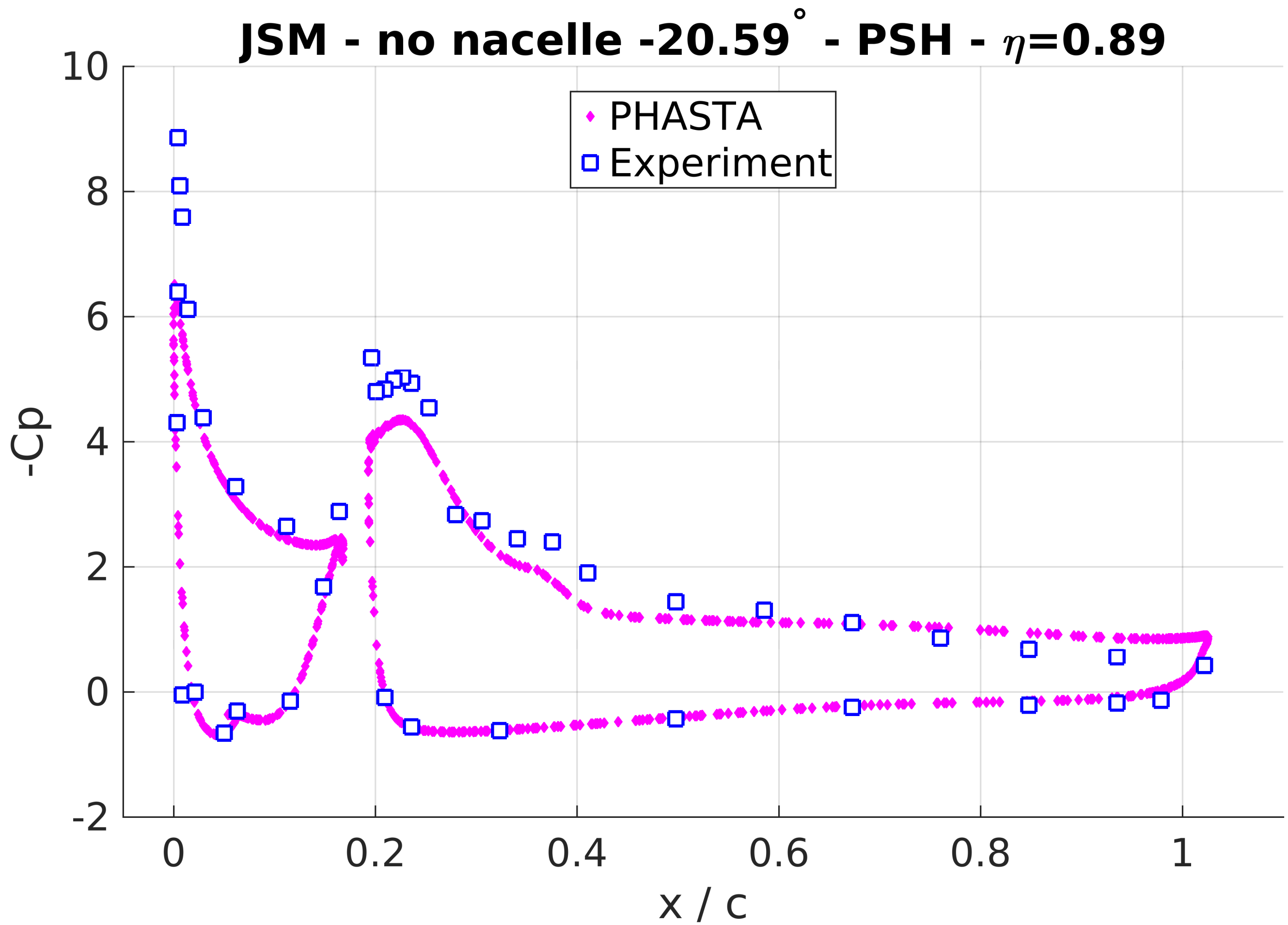
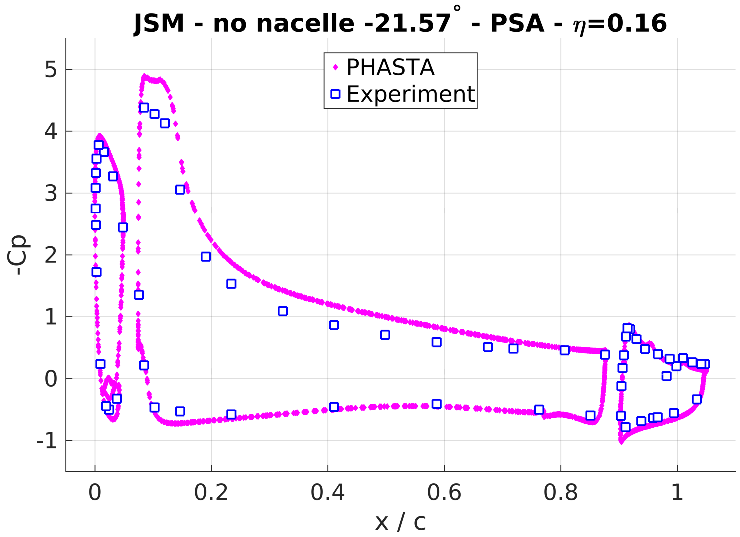
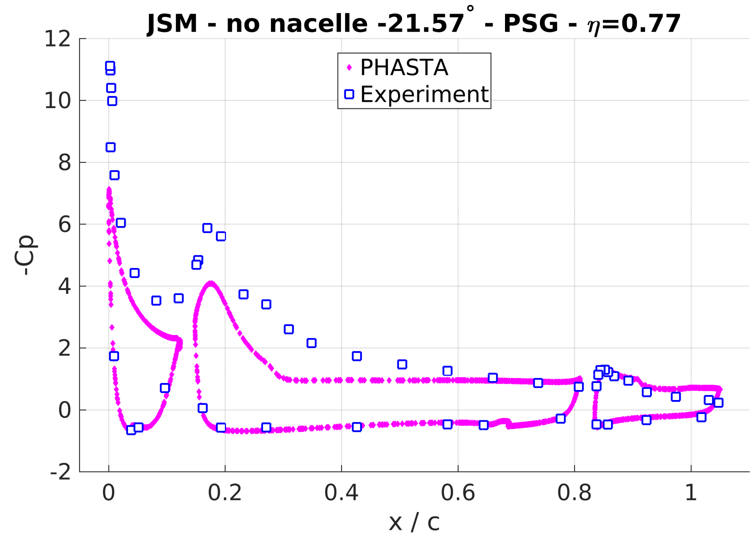


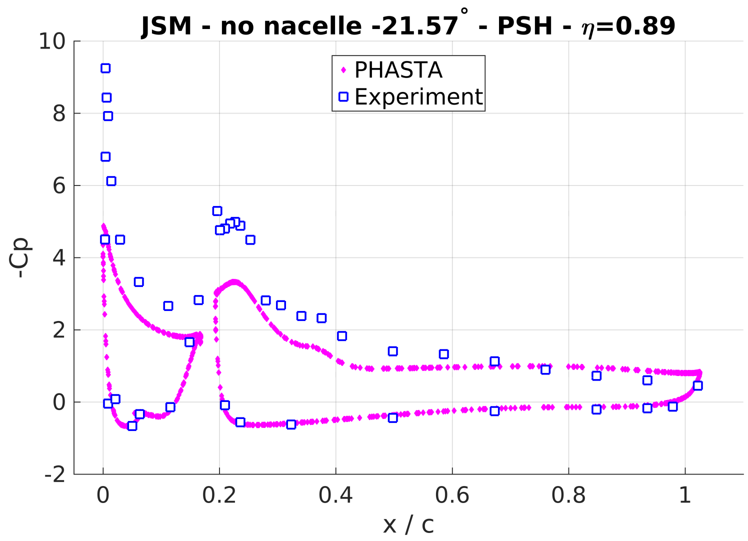
JSM
Pressure Coefficients…and One Less Great



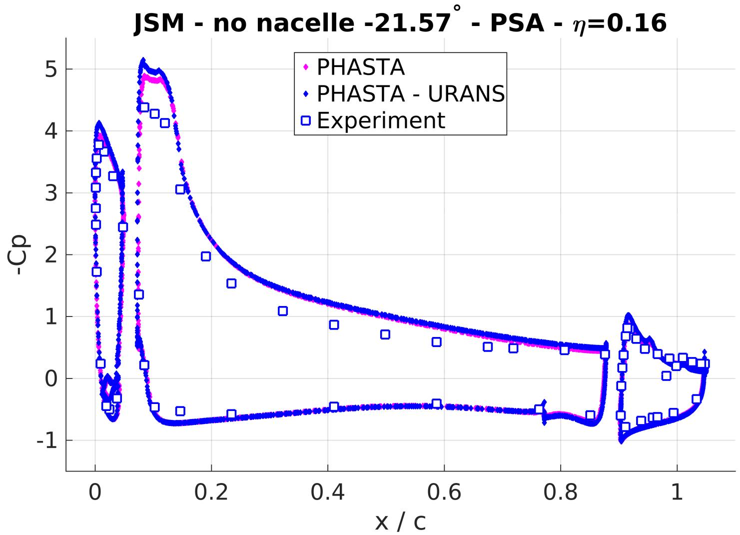
JSM
Pressure Coefficients: Post-Stall: Only the bad ones!

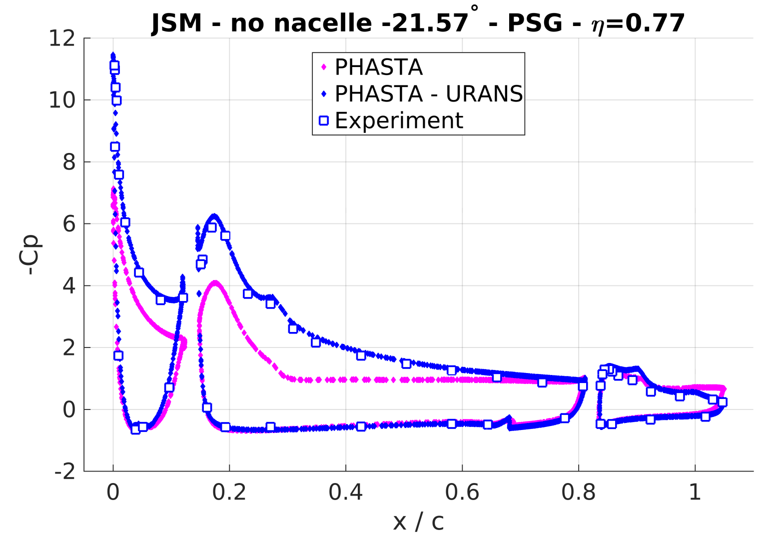




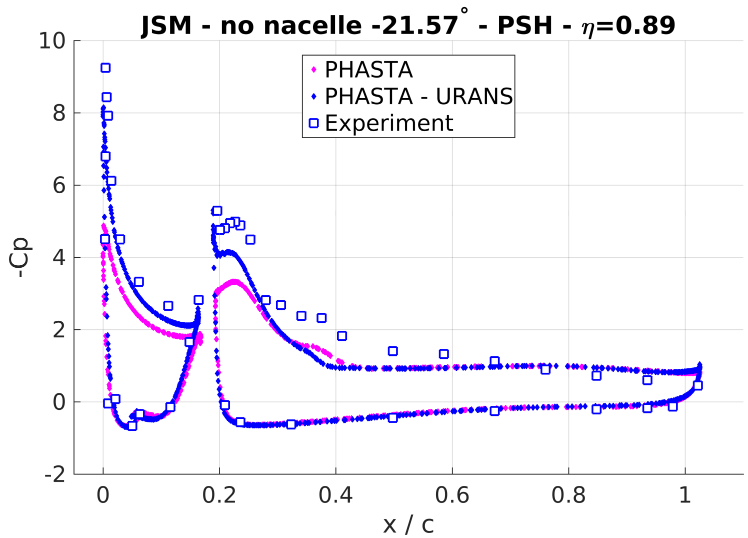


JSM
Pressure Coefficients: Post-Stall: URANS Helps Some



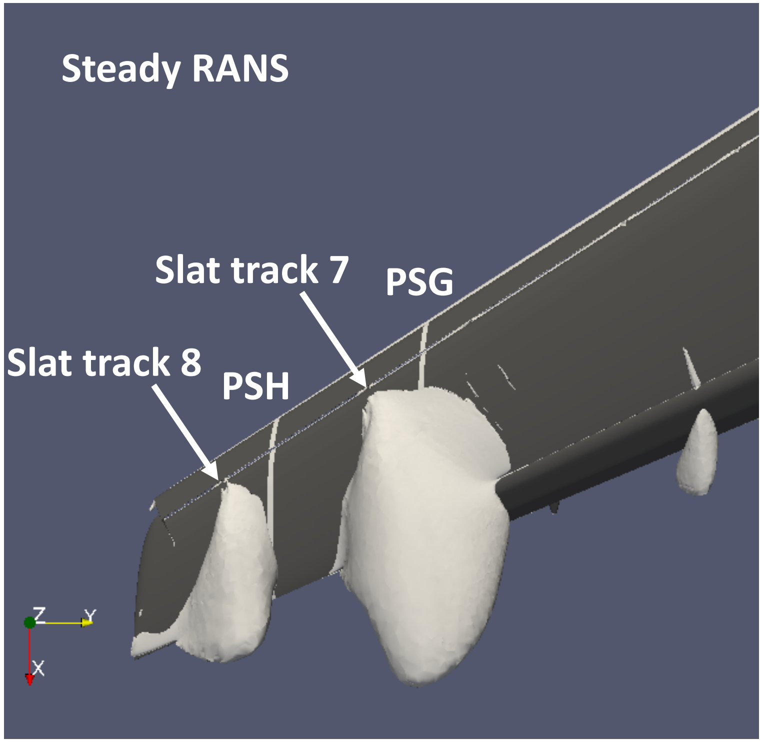


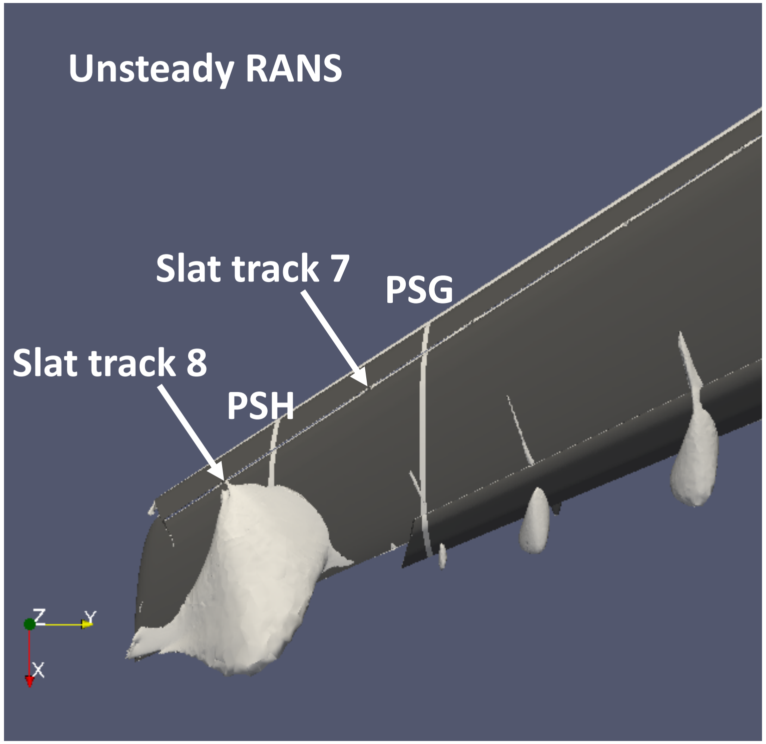
URANS $\mathrm{D_{tf}}$=Dt
U/c=0.05
0.01 no different.
URANS started from uniform flow IC.



JSM
Velocity Isosurfaces: Post-Stall

- Steady RANS predicts massive separation regions at PSG and PSH
- These are caused by vortical structures shed by slat track 7 and 8
- URANS does not predict separation at PSG and has modified shape of separation region at PSH

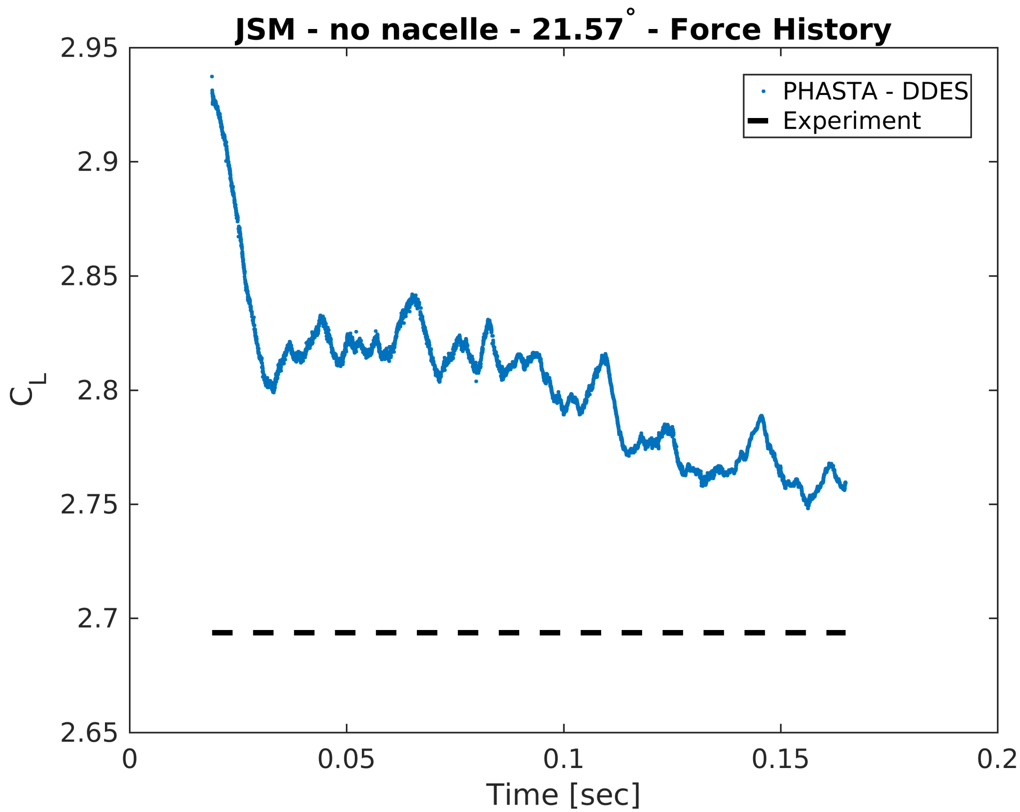




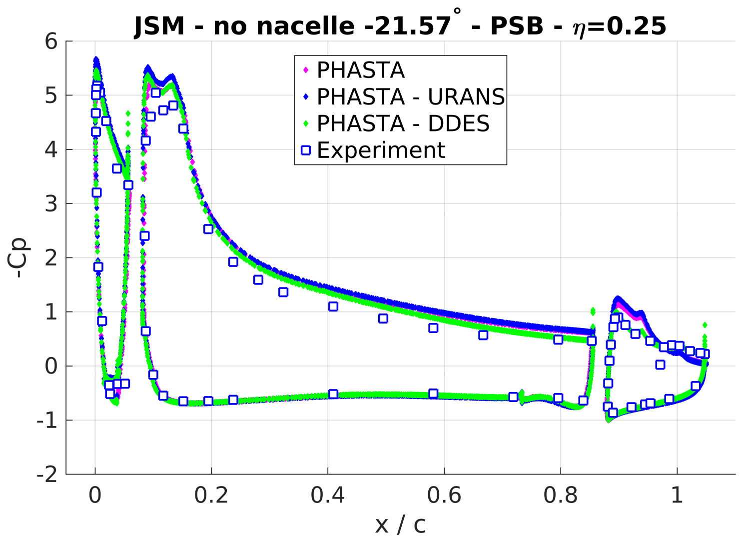
Isosurfaces of $\bar{u} = -0.1\ m/s$

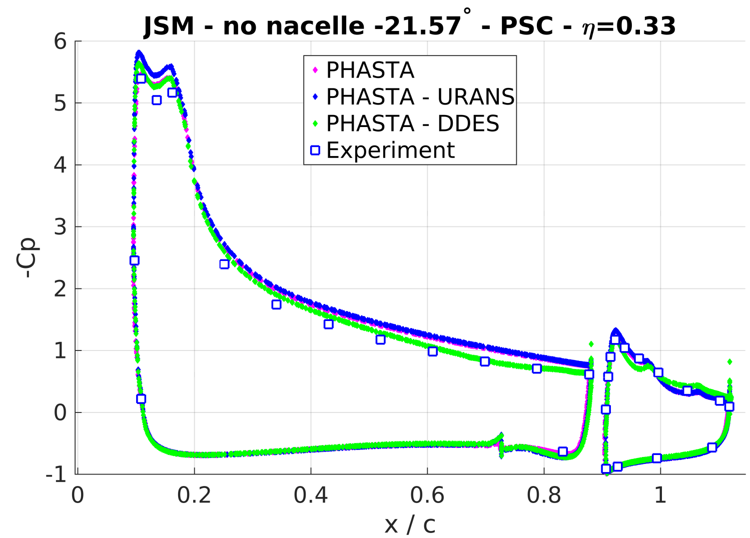
JSM
DDES Force: Post-Stall

- DDES simulation on C2 mesh still in progress. 15k steps=15 chord flights=.15 seconds,
- Lift coefficient approaching experimental value

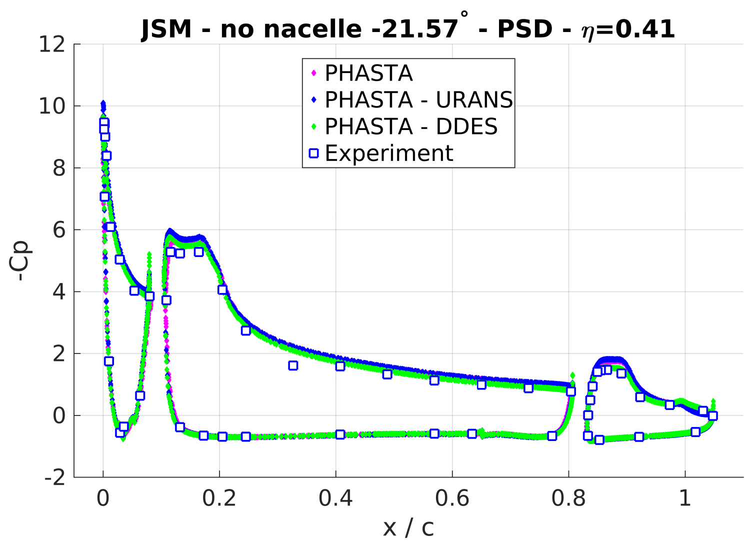


JSM
DDES Pressure Profiles: Post-Stall

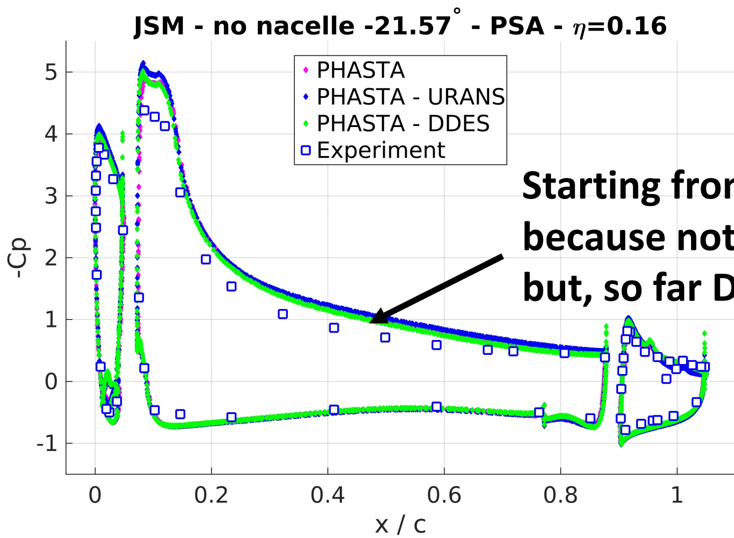




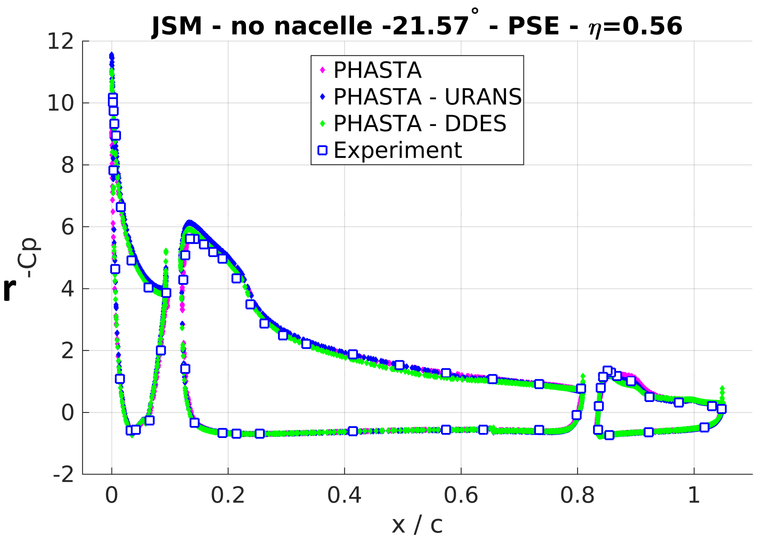
DDES gives a little better prediction over URANS of pressure at the TE of main element and over the flap

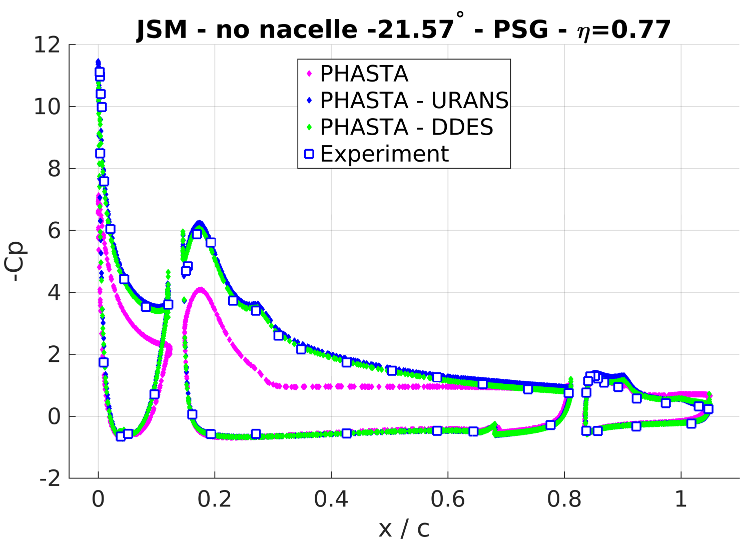


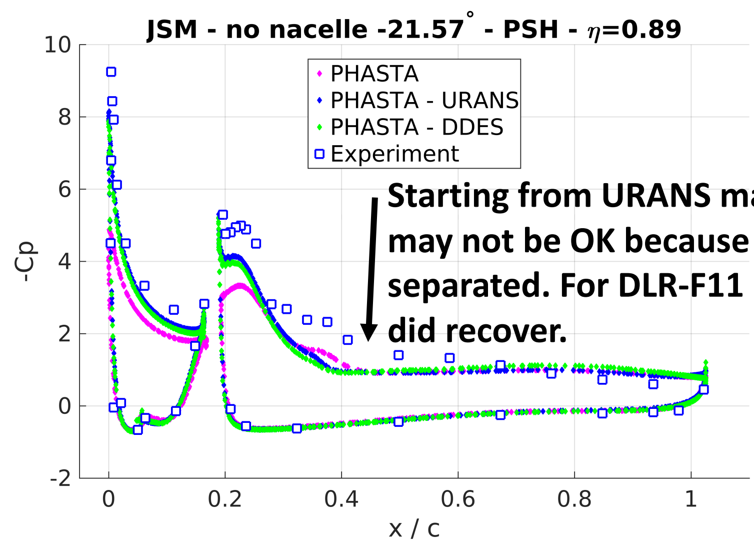
JSM
DDES Pressure Profiles: Post-Stall



Starting from URANS OK because not separated but, so far DDES not either







Starting from URANS may or may not be OK because separated. For DLR-F11 DDES did recover.

Summary

- CRM
  - Good convergence on committee (B1-C/M/F) and Simmetrix grids (C/M)
  - Simmetrix grid used medium wall-normal resolution and this seemed to improve coarse-grid lift prediction dramatically
  - Adaptations of Simmetrix coarse grid ongoing
- JSM (2-c also completed and submitted but no time to discuss) 2-a:
  - RANS (Steady)
    - Pre-Stall Cp predictions excellent for h <= 0.77, premature separation for h =0.89
    - Post-stall Cp h =0.77 separated: separation from outboard, not capturing experiment inboard separation—correct max lift angle/stall, wrong reason.
  - URANS
    - Able to improve h =0.77 but h =0.89 still too separated, and missing root separation.
  - DDES
    - Ongoing….trending towards improved outboard prediction.
    - Likely require adaptivity to get root separation and h=0.89 correct.
    - DLR-F11 was successful but it was a more DDES friendly mesh (less anisotropic).
- Acknowledgments: ALCF INCITE and Early Science Projects for Mira and Theta -- DOE Office of Science Contract DE-AC02-06CH11357; Janus and Summit supercomputers – NSF CNS-0821794 and ACI-1532235 and ACI-1532236. Software components: Simmetrix, SCOREC, Altair, Kitware.

Thanks!